US Army Corps of Engineers

AD-A198 065

GEOTECHNICAL LABORATORY

DTIC FILE COPY

TECHNICAL REPORT GL-88-9

(4)

RETROGRESSIVE FAILURES IN SAND DEPOSITS OF THE MISSISSIPPI RIVER

Report 2

EMPIRICAL EVIDENCE IN SUPPORT OF THE HYPOTHESIZED FAILURE MECHANISM AND DEVELOPMENT OF THE LEVEE SAFETY FLOW SLIDE MONITORING SYSTEM

by

Victor H. Torrey III

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

June 1988

Report 2 of a Series

Prepared for US Army Engineer Division, Lower Mississippi Valley
PO Box 80, Vicksburg, Mississippi 39180-0080

88 3

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report GL-88-9	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES Geotechnical Laboratory 6b. OFFICE SYMBOL (If applicable) CEWES-GE	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39180-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAED Lower Mississippi Valley 8b. OFFICE SYMBOL (If applicable) LMVD	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) PO Box 80 Vicksburg, MS 39180-0080	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

See reverse

12. PERSONAL AUTHOR(S)

Torrey, Victor H. III

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Report of a series	FROM ______ TO ______	June 1988	196

16. SUPPLEMENTARY NOTATION

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Flow slides Mississippi River bank stability Retrogressive failure in sands

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is the second in a series presenting recent tasks associated with the US Army Engineer Division, Lower Mississippi Valley study, "Evaluation of Potentially Unstable Riverbank Sites Below Baton Rouge, LA, and Selection of Measures to Prevent Failure." The objective of that study is to develop defensive/preventative measures to end the threat to safety of main line flood protection levees below Baton Rouge, LA, posed by flow failures in sand deposits.

The case history of a recent large flow failure known as the Celotex slide is presented, analyzed and shown to conform to the current hypotheses concerning the triggering and retrogression of flow failures in sand deposits of the Mississippi River. Additional empirical evidence is drawn from the records of past flow failures to support the current thinking that these failures "run out" in the landward direction on an approximately

(Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

11. TITLE (Continued).

Retrogressive Failures in Sand Deposits of the Mississippi River--Empirical Evidence in Support of Hypothesized Failure Mechanism and Development of the Levee Safety Flow Slide Monitoring System

19. ABSTRACT (Continued).

10 degree angle from the point of initiation riverward in the scour trench or pool upward to the interface between the cohesive topstratum and sand substratum. This geometric trait then becomes the basis for prediction of the amount of potential foreshore (batture) loss and, consequently, for an assessment of threat to levee stability should a flow failure be initiated at depth out in the scour pool at a given site. The computer data base monitoring system devised by the New Orleans District to perform periodic checks on susceptible sites is presented.

The final portion of the report addresses historical river movement and its implications for the reach of river below Baton Rouge, LA. Hydrographic surveys conducted at intervals over the period 1879-1975 were judged to imply trends which may negatively impact levee safety relative to flow slides in the future.

Accession For	
NTIS GRA&I	☑
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

PREFACE

This document is a progress report describing and discussing recent tasks associated with the US Army Engineer Division, Lower Mississippi Valley (LMVD) study, "Evaluation of Potentially Unstable Riverbank Sites Below Baton Rouge, LA, and Selection of Measures to Prevent Failure." The work has been under the immediate purview of Mr. Frank J. Weaver, Chief, LMVED-G.

This report was prepared by Dr. Victor H. Torrey III, Research Group, Soil Mechanics Division (SMD), Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES). Mr. Bobby Odom of the Information Products Division, WES, edited the report.

Information pertaining to the New Orleans District Levee Safety Flow Slide Monitoring System was provided by Mr. Jay Joseph of LMNED-F, who is primarily creditable for its capabilities.

Mr. Joseph Dunbar, Site Characterization Unit, Engineering Geology and Rock Mechanics Division, GL, WES, compiled the data pertaining to historical changes in Mississippi River alignment below Baton Rouge, LA.

This work was performed under the general supervision of Mr. Clifford L. McAnear, Chief, SMD, and Dr. William F. Marcuson III, Chief, GL.

COL Dwayne G. Lee, CE, is Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic yards	0.7645549	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
inches	2.54	centimetres
square feet	0.09290304	square metres

RETROGRESSIVE FAILURES IN SAND DEPOSITS OF THE MISSISSIPPI RIVER

Report 2

Empirical Evidence in Support of the Hypothesized Failure Mechanism and Development of the Levee Safety Flow Slide Monitoring System

PART I: INTRODUCTION

Background

1. This report represents a continuation of efforts by the Lower Mississippi Valley Division (LMVD), US Army Corps of Engineers, to develop an effective plan for and means of protecting the integrity of main line Mississippi River levees from the threat of flow slides in sand deposits. Entailed in these mission objectives has been the necessity of achieving the following milestones:

- a. It has been necessary to develop an understanding of the triggering and subsequent retrogression of this type of failure to permit a prediction of its potential size and, therefore, the existence of a threat to levee stability. It is believed that the failure mechanism is understood and is that of retrogression in dilatant sand as previously described in the report by Torrey, Dunbar and Peterson (1988). There is every evidence that the triggering is by severe scour which "oversteepens" the underwater slope in the sands.
- b. An understanding must be developed of river attack specifically in the "oversteepening" of underwater slopes in sand in all its apparent phases such as high water versus low water and shallow versus deep. The work is essentially at "square one" in this area.
- c. Susceptible riverbank sites/reaches must be identified. This is largely accomplished, but it is not enough to only say "susceptible." The question must not only be narrowed to a strictly site specific one, but must also include the ability to say whether or not a flow slide is likely to occur at a given site and the potential threat to the levee it may represent.
- d. An effective monitoring system must be developed which will identify site-specific direct threat to the stability of the levee. This will permit more rational decisions concerning defensive measures and their prioritization. A system based on

the concept of the failure mechanism has been instituted. Its effectiveness remains to be proven.

e. Benign methods must be developed to prevent or retard the occurrence of flow failures which means improved bank protection techniques or modifications of current procedures. By "benign" methods, it is meant that measures intended to stop flow failures must not alter river behavior such that serious problems are generated upstream or downstream. This may prove to be the very most difficult task of all. Not the least obstacle in these efforts is the fact that turbidity/depths of water and the physical nature of revetment have thus far thwarted the identification of a method(s) which can "see" bank protection over its extent clearly and accurately so that assessments of performance/behavior can be made with confidence. River Engineering Branch is proceeding with some significant efforts in this problem domain.

The above required achievements clearly indicate the interdisciplinary nature of the problem. Though slow, expensive and hard won in some cases, progress has been made in the attack on all the necessary elements listed above.

2. It is not practical to provide the reader of this report a background statement which would serve to synopsize all the progress that has been made. In addition, this report principally addresses only geotechnical aspects. The report by Torrey, Dunbar and Peterson (1987) presents an overview of past work.

Purpose and scope

3. This is a progress report documenting several specific tasks accomplished since those presented in Report 1 (Torrey, Dunbar and Peterson 1988). The following items are included in this report:

a. The case history of the 1985 flow failure at the so-called Celotex site is given and discussed.

b. The computer data base system for monitoring potential flow slide sites which is currently in use by the New Orleans District (NOD) is described. The specific method for predicting batture loss is presented with supporting arguments and empirical data including that of the Celotex failure.

c. A discussion of river attack and its implications based on movement of the river channel over the last 90 years is presented. Some statistical data summaries of changes in the river's characteristics over the period of record are also given.

d. Recommendations are made for future directions of the work.

PART II: CASE HISTORY OF THE CELOTEX BATTURE AND LEVEE FAILURE OF 30 JULY 1985

Background

4. It is not the purpose of this case history presentation to duplicate the considerable work of the NOD contained in its internal report, "Mississippi River Levees, Item M-100.4-R, Celotex Levee and Batture Restoration, Final Report," May 1987.* That reference is cited here as the source of several figures and event facts given in the following discussions without a repetitive identification of the source. The specific purpose of this part is to document the failure in this more formal report and address the failure in the context of the general flow slide problem.

Failure

5. Around 2 a.m. on the morning of 30 July 1985, a tugboat operator reported to NOD Operations Division his observation of a riverbank failure at mile 100.4 above head of passes (AHP) on the west bank (right descending) of the Mississippi River in the Jefferson Levee District, approximately 0.5 mile south of Westwego, LA, and within the Greenville Bend revetment reach. The failure progressed landward and involved the levee crown by 6 a.m. Figure 1 is a vicinity map showing the failure area. Figure 2 shows the specific location of the failure. In Figure 2, it is seen that landward of the levee near the failure is the industrial complex of the Celotex Corp. Consequently, the failure is referred to by that name. An aerial photograph also showing the failure location is given in Figure 3.

6. By mid-morning of 30 July, the NOD had mobilized for emergency treatment of the problem. Fathometer surveys of the failure were initiated, and soil boring crews were called in to investigate a levee setback alignment. It was low water season, and the levee had not been actually breached. It was also hurricane season which presented a potential for elevated river levels and wave wash should a storm develop and come up the river from the Gulf of Mexico.

---

* Unpublished report.

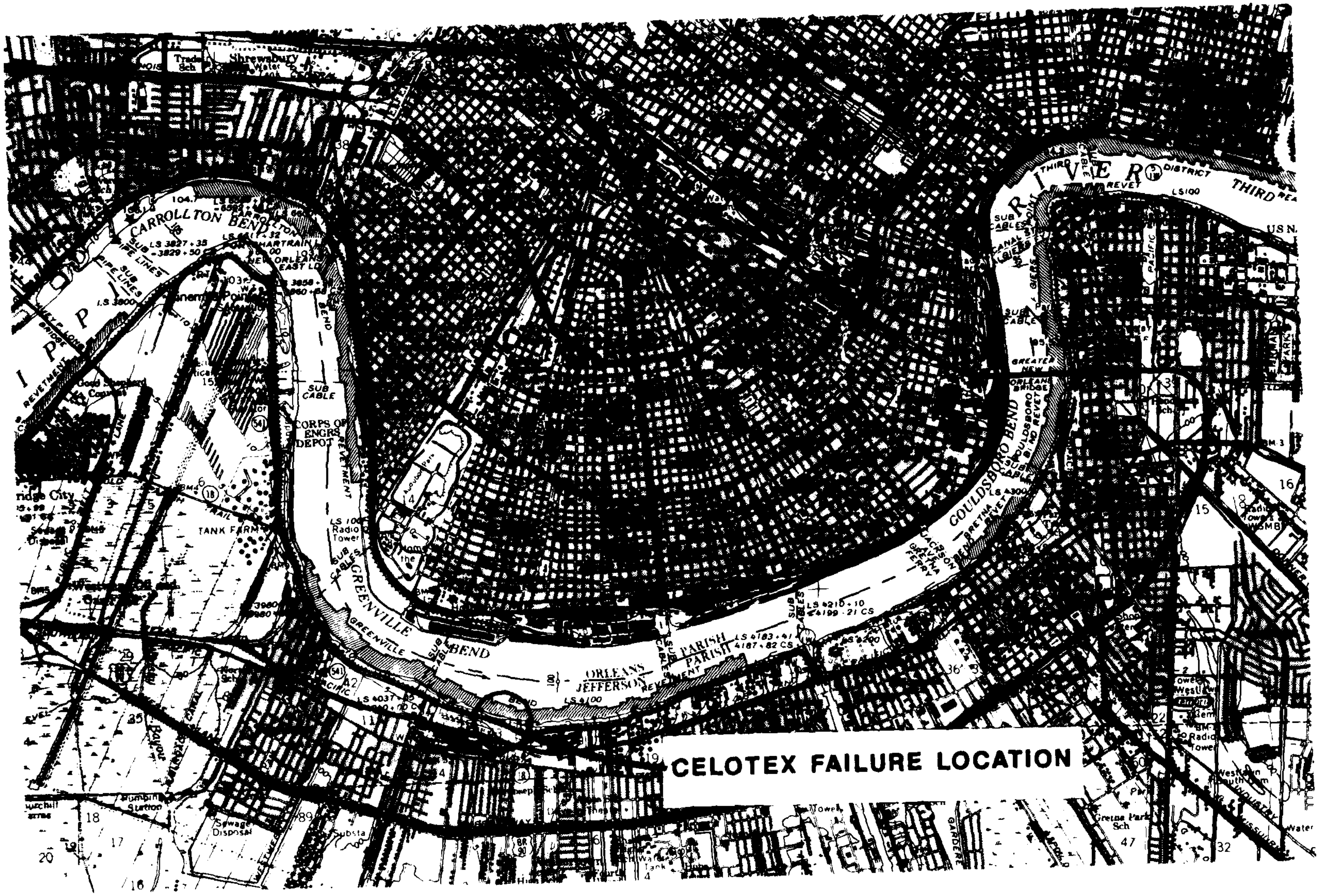


Figure 1. Vicinity map, Celotex batture and levee failure

NOTE: *Figure taken from* Mississippi River, Hydrographic Survey 1973-1975. Levee stationing is not current.

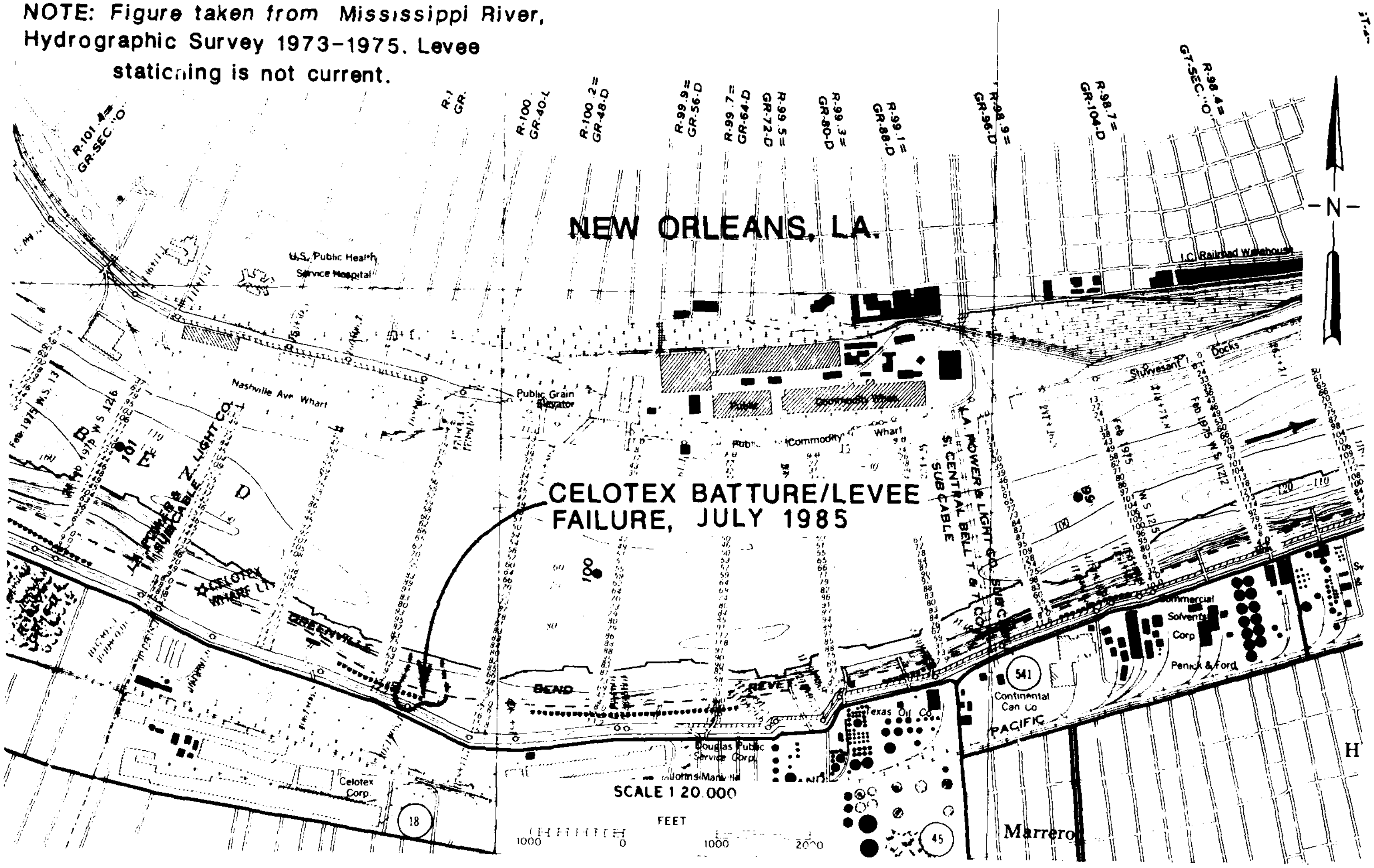


Figure 2. Location map, Celotex batture and levee failure

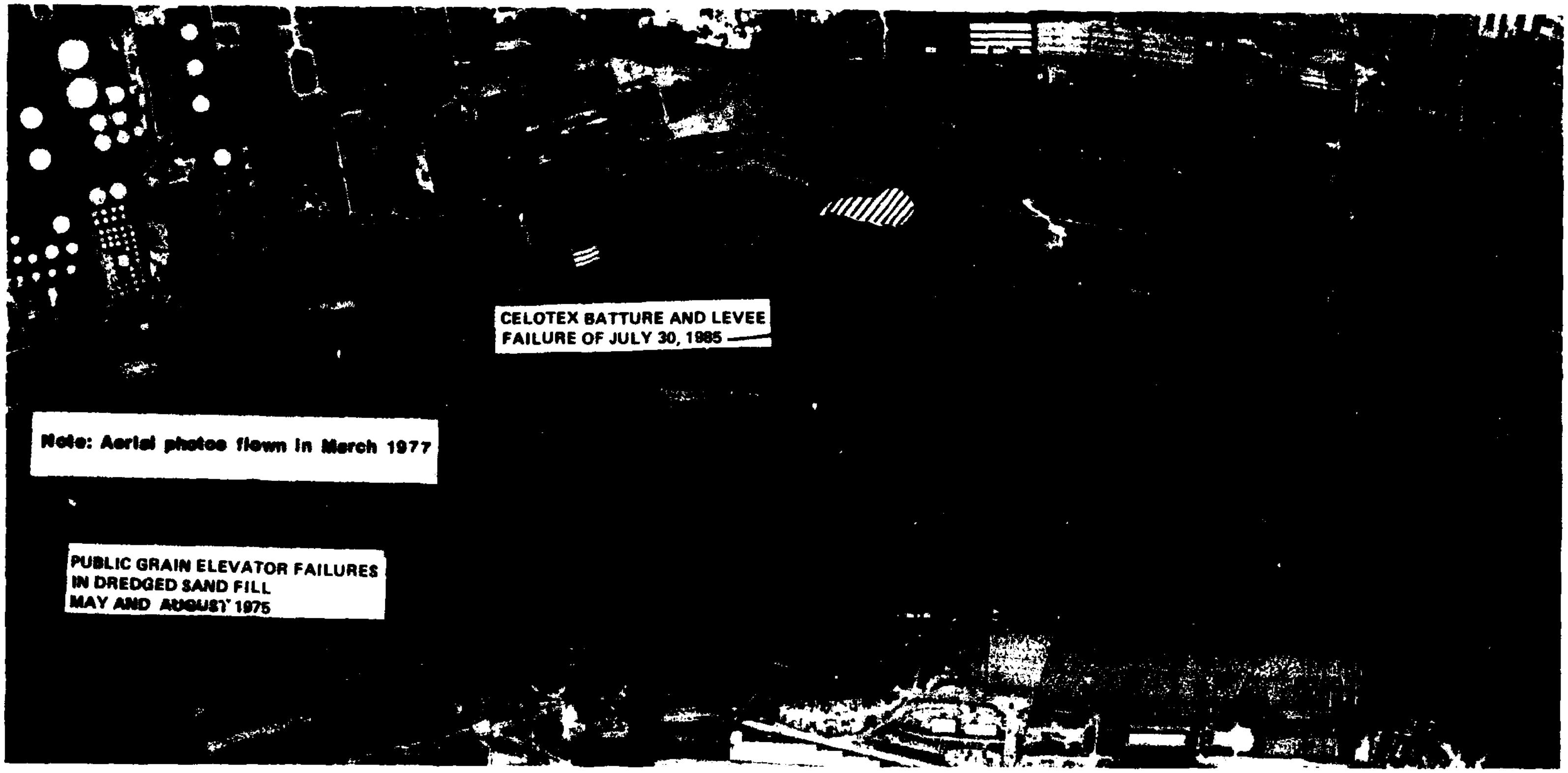


Figure 3. Aerial photo showing location of the Celotex failure

7. On 31 July the drilling crews went to work in the setback area and immediately encountered a hard material at a depth of only 3 ft below the surface. The material was determined to be asbestos with a thickness of about 3.5 ft. Drilling was halted until the crew members could be provided with proper protective wear against the hazards of the asbestos. Drilling proceeded along a line within the failure area to determine if any overburden material remained within the scar.

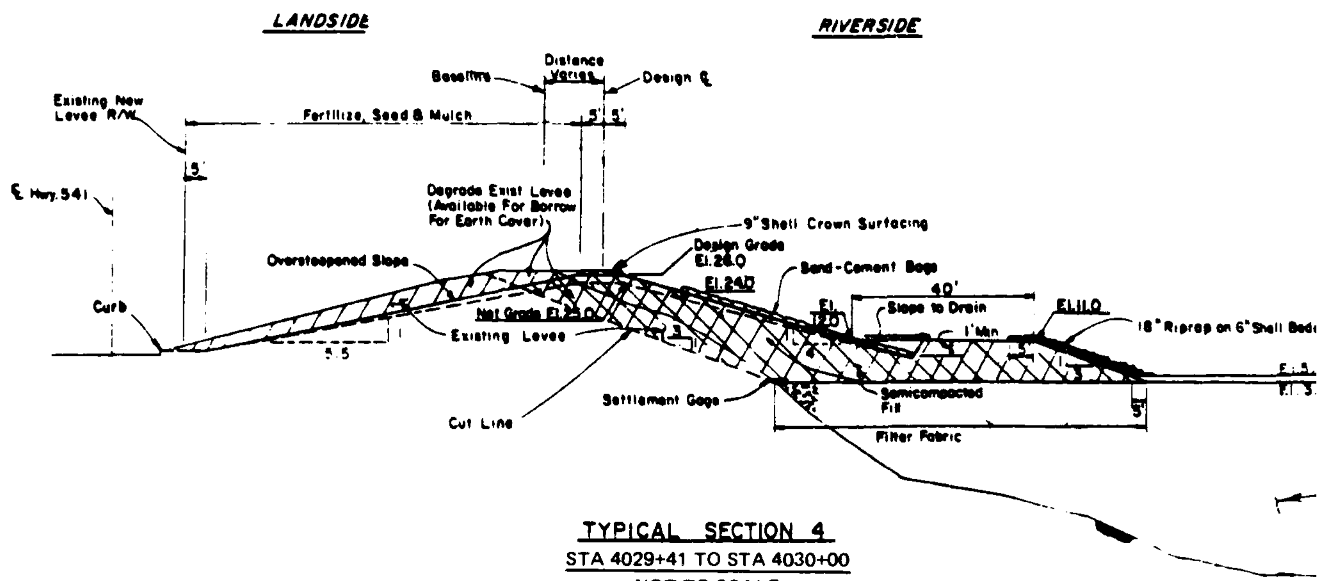
8. The setback alignment drilling revealed that the asbestos represented an old industrial waste pit. The several negative ramifications of a hazardous waste dump along the setback alignment caused LMVD to instruct NOD to investigate alternative repair designs for restoring the batture and rebuilding the levee to avoid a setback. By 23 August, the alternatives for restoration had been assessed, the decision to restore the batture and levee in place and how to do it had been made, plans and specifications had been prepared and approved, and the contract had been advertised. The contract was awarded on 30 August and the work completed on 28 November 1985.

9. The innovative and cost-saving restoration technique is best described by the following construction sequence. A typical section is shown in Figure 4.

- a. The failed batture was rebuilt with shell to el 3.0 ft.* Approximately 272,000 cu yds of shell was placed in 60 to 70 ft of water.
- b. The remaining portion of the failed levee was reshaped to receive a new fill.
- c. Filter cloth was placed as a separator between new levee berm fill and the shell backfill. Prior to placement of the filter cloth, the shell batture was raised to el 5.0 in the area of the new levee fill to avoid a rising river stage.
- d. Construction of the new levee berm to el 7.5 with semicompacted fill proceeded to keep the work above the rising river.
- e. The shell batture/bank was armored with a 5-ft-thick layer of riprap stone, and the new levee and buttress berm were completed.
- f. The slope of the buttress berm was armored with an 18-in.-thick layer of stone.
- g. The riverside levee slope was protected by placing sand-cement filled bags.

---

* All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

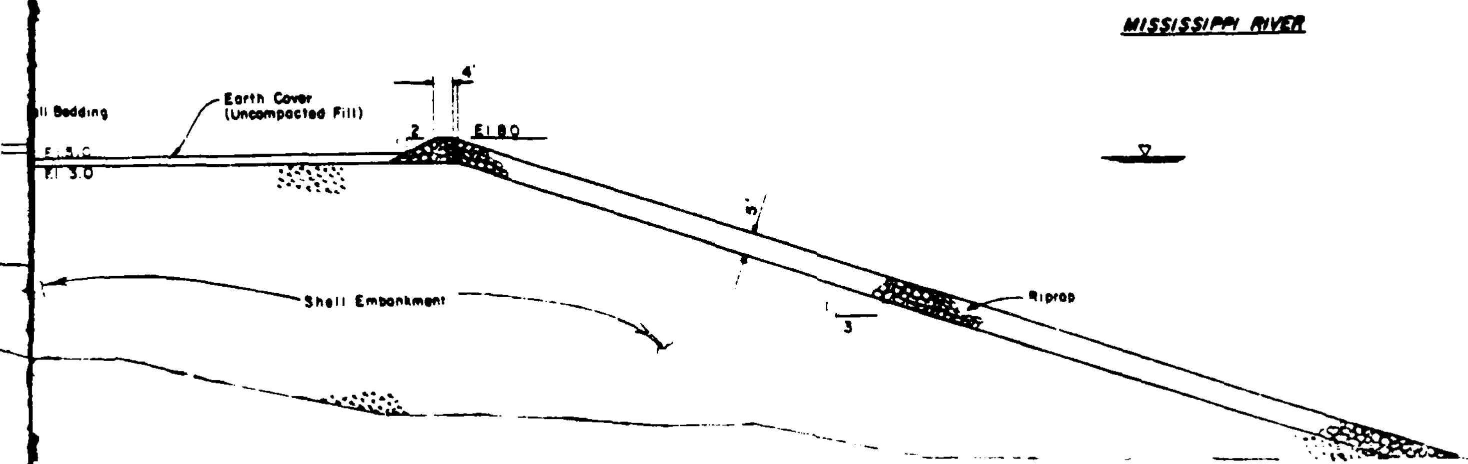


TYPICAL SECTION 4

STA 4029+41 TO STA 4030+00

NOT TO SCALE

Figure 4. Batture and levee res



at restoration, Celotex failure site

h. The armored shell riverbank was revetted with articulated concrete mattress (not shown in Figure 4).

10. The author employed the Fathometer surveys and the boring information within the failure area to produce the contour map shown in Figure 5. Sections are plotted in Figure 6. Three-dimensional microcomputer images of the failure are given in Figures 7 and 8. The plan and sections of the failure reveal the bottleneck plan view and relatively flat bottom slopes typical of a flow slide. The line of borings taken between Greenville Bend revetment ranges U-18 and U-19 for the purposes of determining if overburden remained in the scar proved to be a fortuitous accident with respect to their position in revealing some important aspects of the failure's appearance as well as suggesting a sequence of events to be addressed later. This circumstance emphasizes the need that surveys of future flow slides be done in greater detail so that quality contour views can be constructed. Survey range lines should never be more than 100 ft apart and should extend to the thalweg. Portions of failures above water should also be surveyed after the fashion necessitated by the repair method for Celotex. The surveys should be initiated as close to the failure event as practicable even if the failure is only to be graded and revetted or even if the failure is in unrevetted bank. Such quality physical pictures of flow failures are now especially important data to help eliminate any doubts about predictions of potential batture loss included in the flow slide bank monitoring system to be discussed in the next part of this report. Simple microcomputer software is available to draw contour maps and three-dimensional views which can be rotated and sectioned at will.

Discussion of Failure

11. The Celotex failure adds a new dimension to the problem of flow slides below Baton Rouge for the simple reason that it occurred during the low water period of the year. In the past, flow slides have been associated with high water, point bar deposits, and a position on the upstream end of the inside of a bendway. The reasons for the occurrence of Celotex during low water are not known. Is something going on in scour pools during low water that is not perceived? Celotex is not the only low water flow failure of which the author is aware. During the summer of 1980, a flow slide developed at the downstream end of the Montz revetment (left descending bank, at

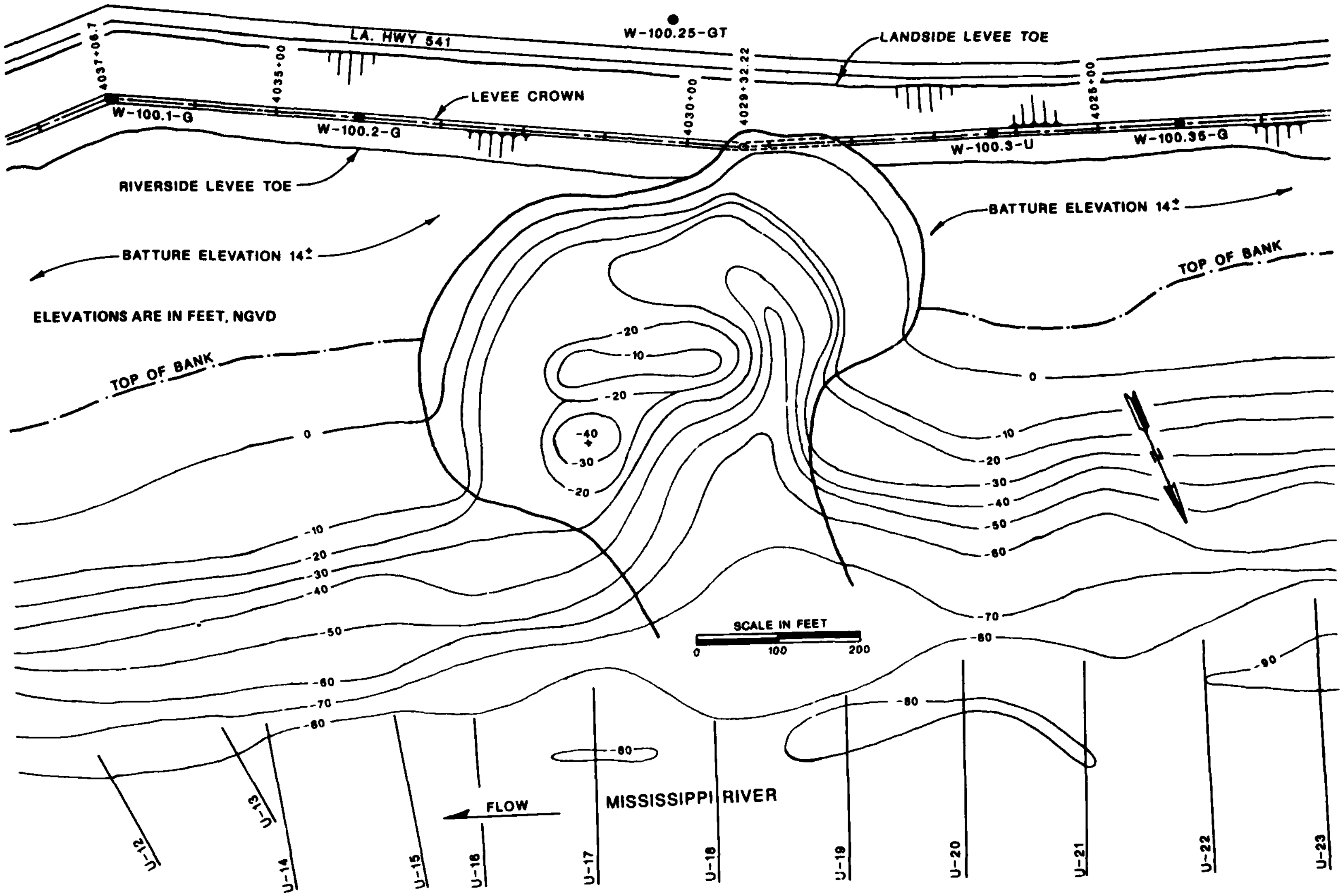
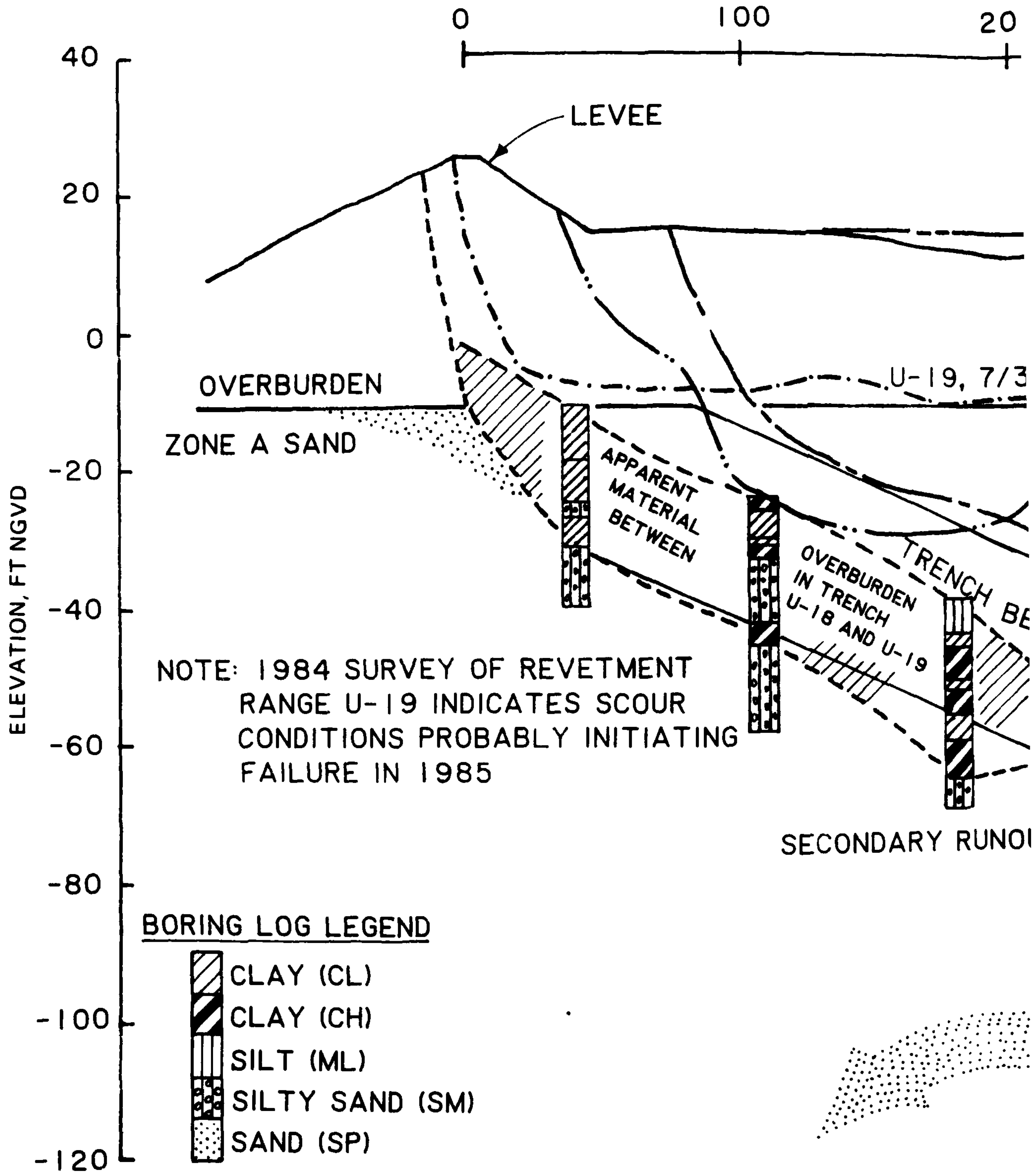


Figure 5. Contour map of the Celotex batture and levee failure



0
100
20
40
20
0
-20
-40
-60
-80
-100
-120
ELEVATION, FT NGVD
LEVEE
OVERBURDEN
ZONE A SAND
U-19, 7/3
APPARENT MATERIAL BETWEEN
OVERBURDEN IN TRENCH U-18 AND U-19
TRENCH BE
NOTE: 1984 SURVEY OF REVETMENT RANGE U-19 INDICATES SCOUR CONDITIONS PROBABLY INITIATING FAILURE IN 1985
SECONDARY RUNOU
BORING LOG LEGEND
CLAY (CL)
CLAY (CH)
SILT (ML)
SILTY SAND (SM)
SAND (SP)

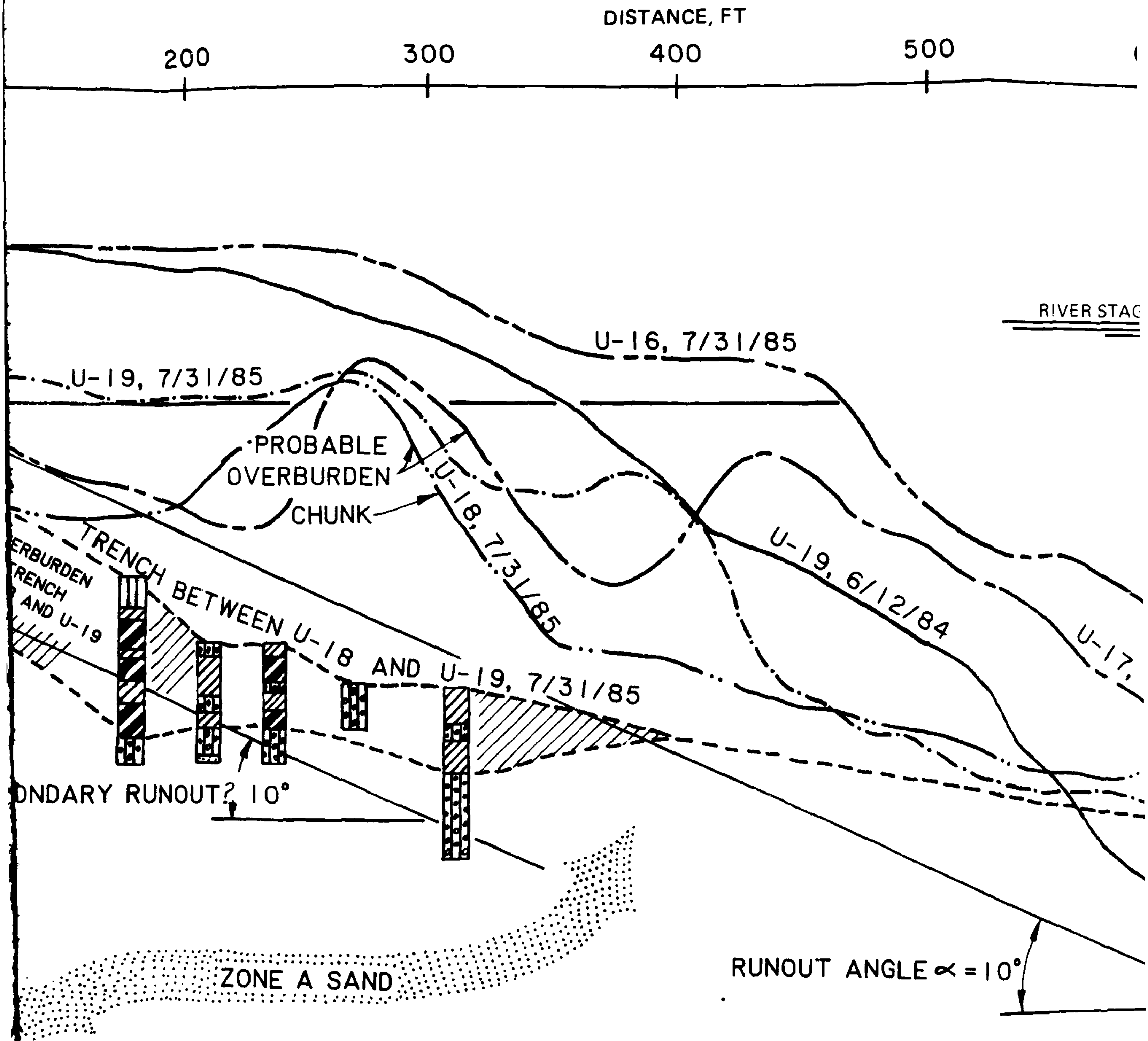
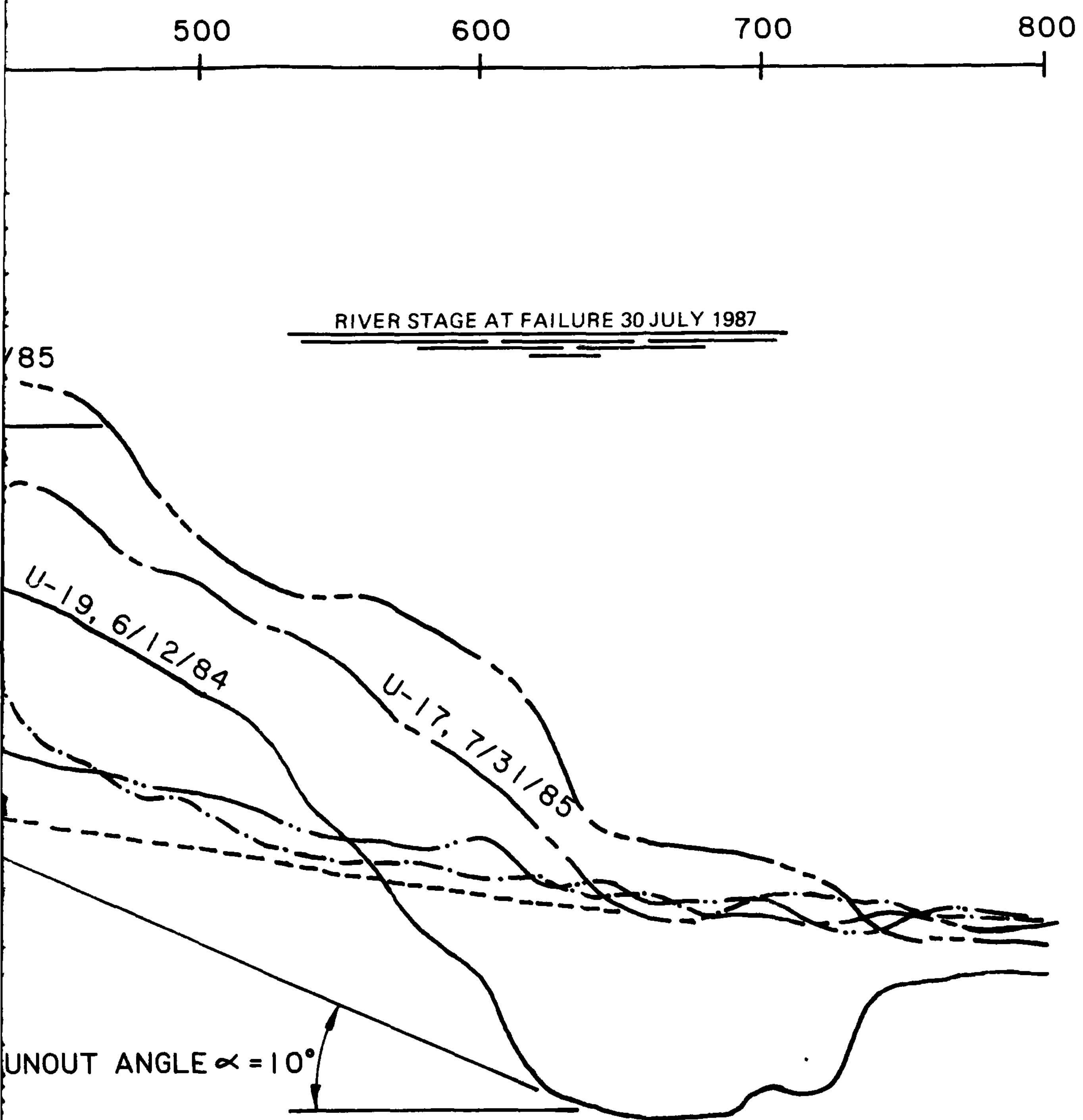


Figure 6. Cross sections of the Celotex failure

2



500
600
700
800
RIVER STAGE AT FAILURE 30 JULY 1987
/85
U-19, 6/12/84
U-17, 7/31/85
UNOUT ANGLE ∝ = 10°

2
1
3

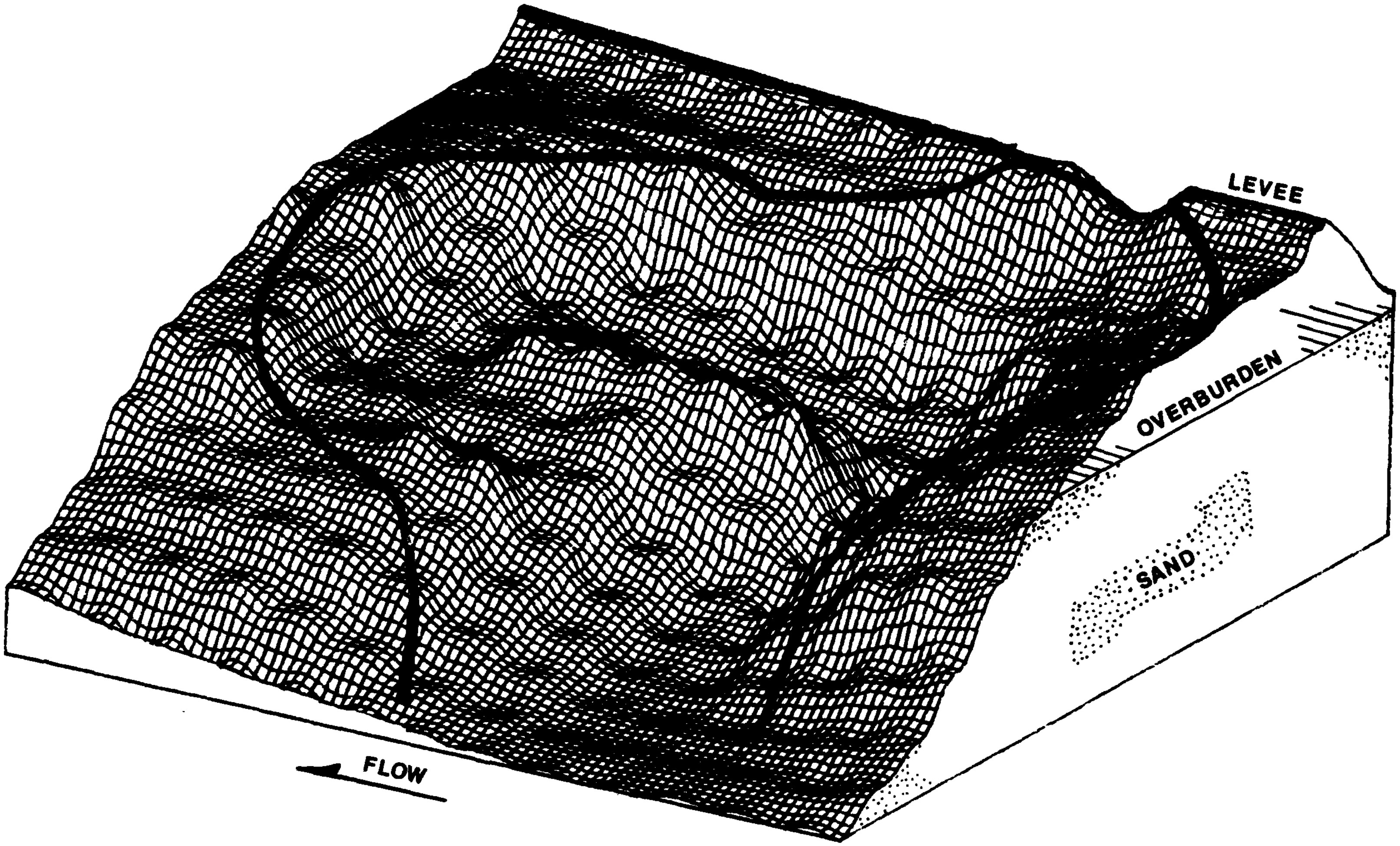


Figure 7. Computer image of the Celotex failure viewed from a position upstream

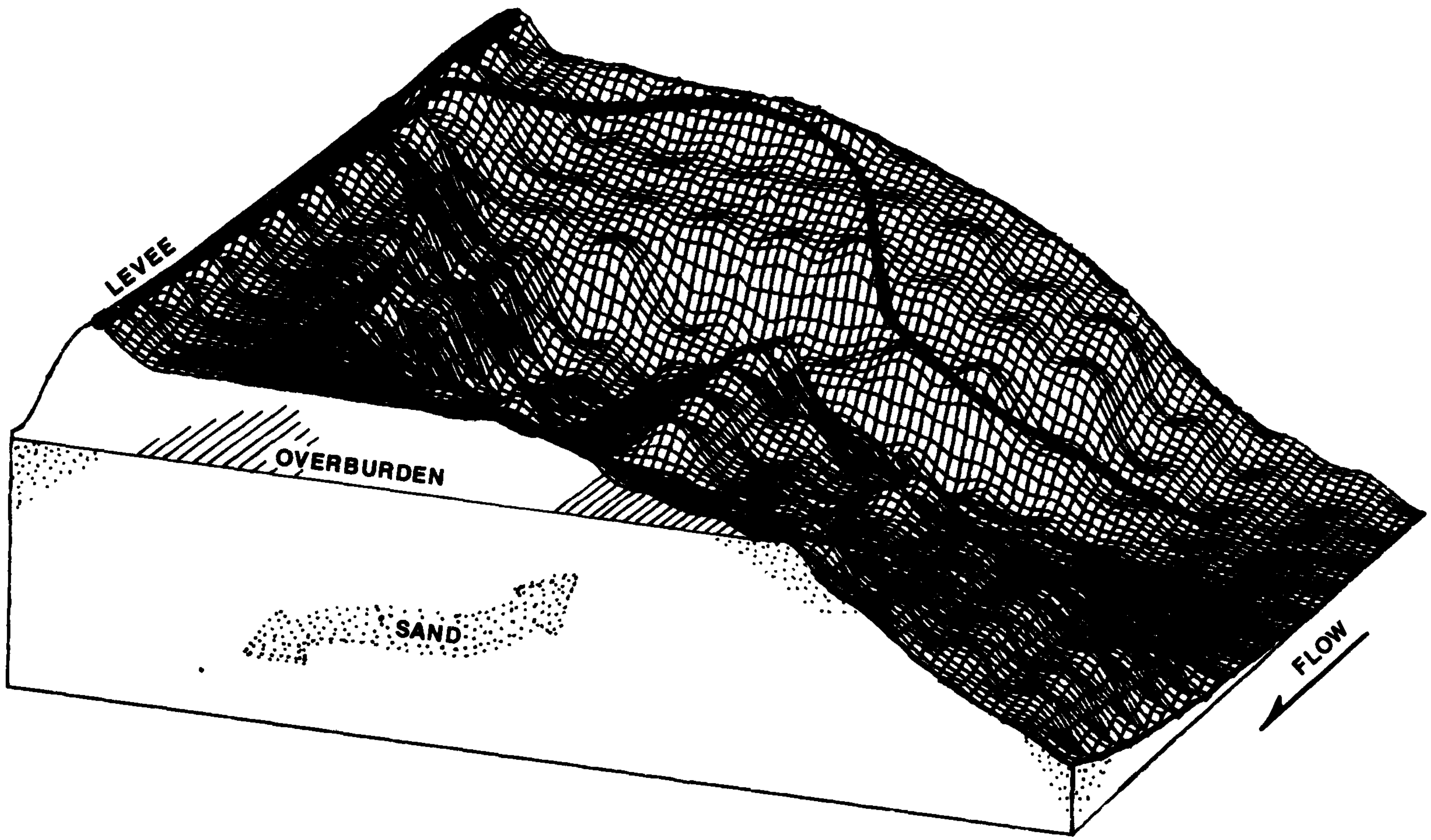
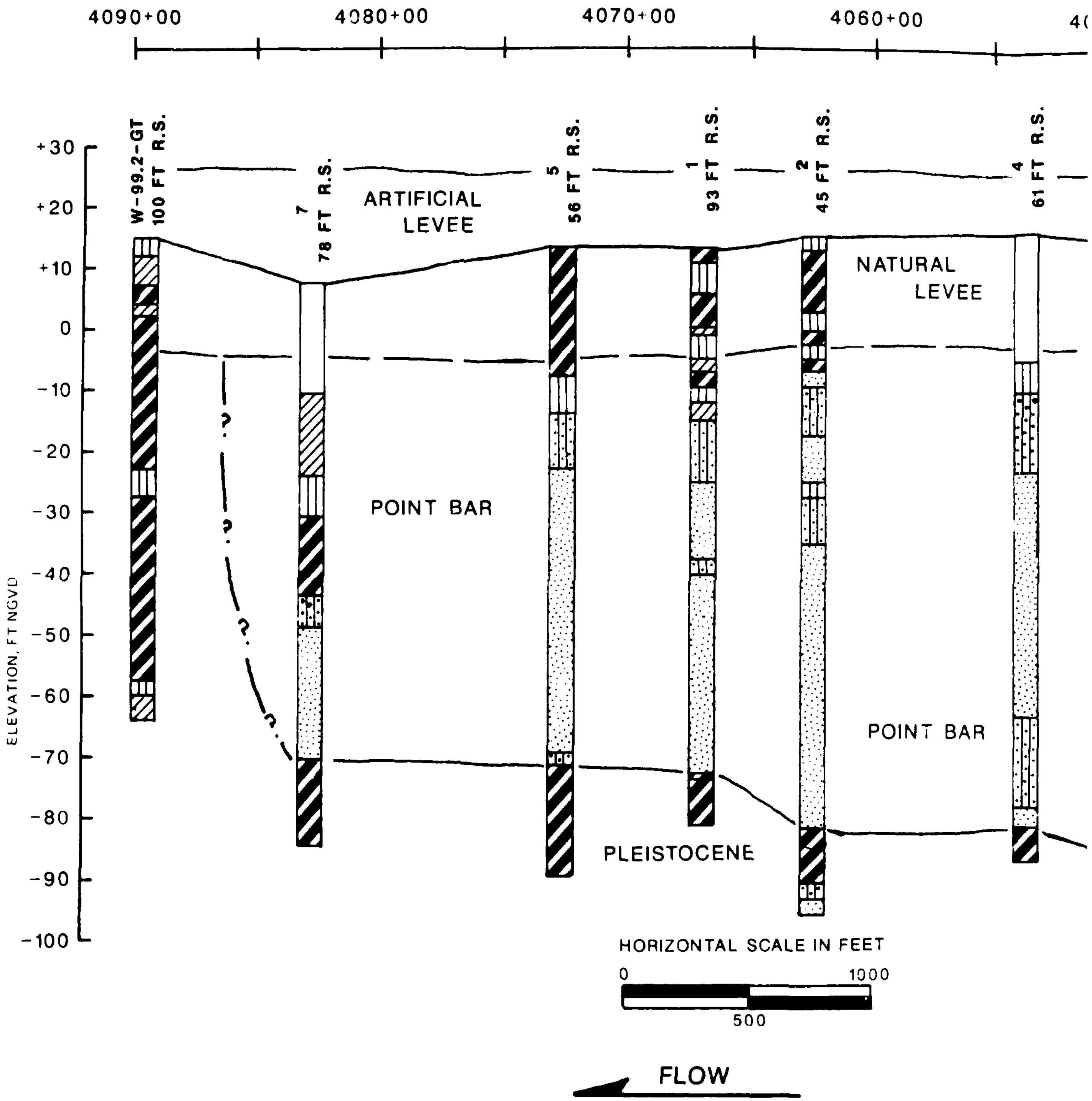


Figure 8. Computer image of the Celotex failure viewed from a position downstream

approximately mile 129.9 AHP). However, it has long been known that severe scour conditions are produced directly at the downstream end of revetment mattresses. In fact, this knowledge has lead to careful consideration of the downstream extent of placement of revetment mattresses below Baton Rouge to ensure that such scour does not trigger a flow slide which might threaten the levee. The Celotex failure was clearly not of this nature in that it was located within a revetted reach, not at the end of the reach. The bank reach exhibits the particularly dangerous soil stratigraphy of thin overburden over a thick deposit of fine sands and silty sands. The soil profile is given in Figure 9. From Figure 9 it can be seen that the failure occurred in an abandoned channel deposit. This deposit, as well as the point bar deposits on either side, were previously classified as susceptible to flow failures.

12. The stage hydrograph for the Mississippi River based on the Carrollton gage (about 2.5 miles upstream of the failure location) is shown in Figure 10. On the day of the failure (30 July), the river had reached its lowest stage of the period at about el 2.0. The construction sequence for the batture and levee restoration given previously in paragraph 9 states that the river was on the rise during repair operations. The river had been on the fall prior to the failure since about 21 June at an average rate of only about 0.1 ft per day. Years ago, in the LMVD Potamology Investigations studies, seepage gradients in sands and silty sands resulting from such rates of falling stage were dismissed as playing a role in the general case of instability of Mississippi Riverbanks (Clough 1966) as well as in triggering of flow failure (US Army Engineer Waterways Experiment Station (USAEWES) 1950).

13. At the time of failure, the most recent hydrographic surveys of the riverbank reach including the Celotex failure site were those sections run during June 1984. The bank section seen at that time for revetment range U-19 is shown in Figure 6. Evident from that section is the presence of a significant scour trench at the toe of the bank slope. The other sections taken during that same survey indicate that the trench ended less than 200 ft downstream before reaching revetment range U-18. It is possible to track the trench upstream in the 1984 survey into the "permanent," deep scour pool situated in the Greenville Bend. It is conjecture that the scour trench existed at revetment range U-19 on the day of failure. However, on the strength of all the evidence to date regarding the triggering of flow failures, it is believed that the trench was present, and that severe scour produced an


4090+00
4080+00
4070+00
4060+00
W-99.2-GT
100 FT R.S.
7
78 FT R.S.
5
56 FT R.S.
1
93 FT R.S.
2
45 FT R.S.
4
61 FT R.S.
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
ELEVATION, FT NGVD
ARTIFICIAL LEVEE
NATURAL LEVEE
POINT BAR
POINT BAR
PLEISTOCENE
HORIZONTAL SCALE IN FEET
0
500
1000
FLOW

Fig

|

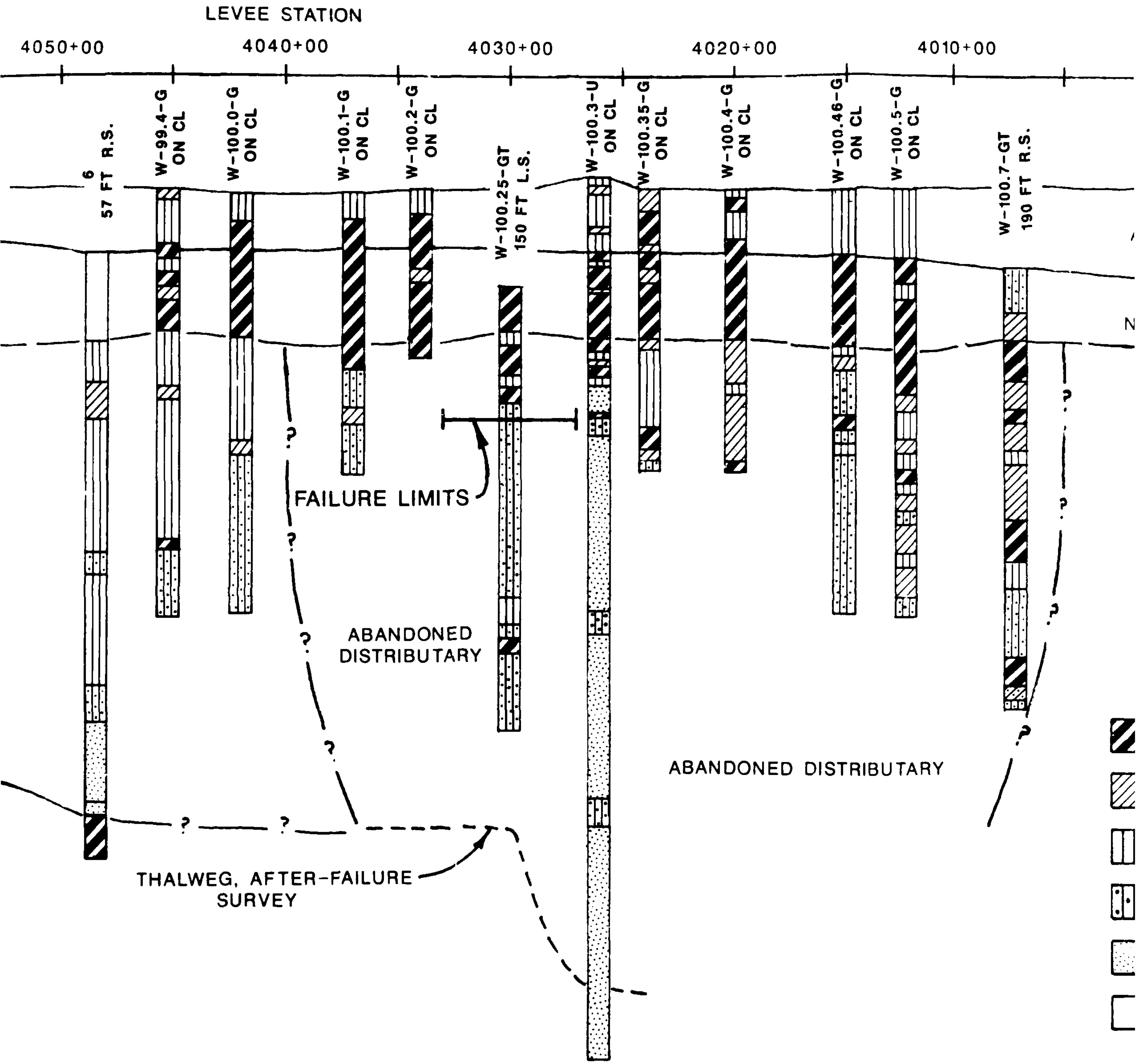
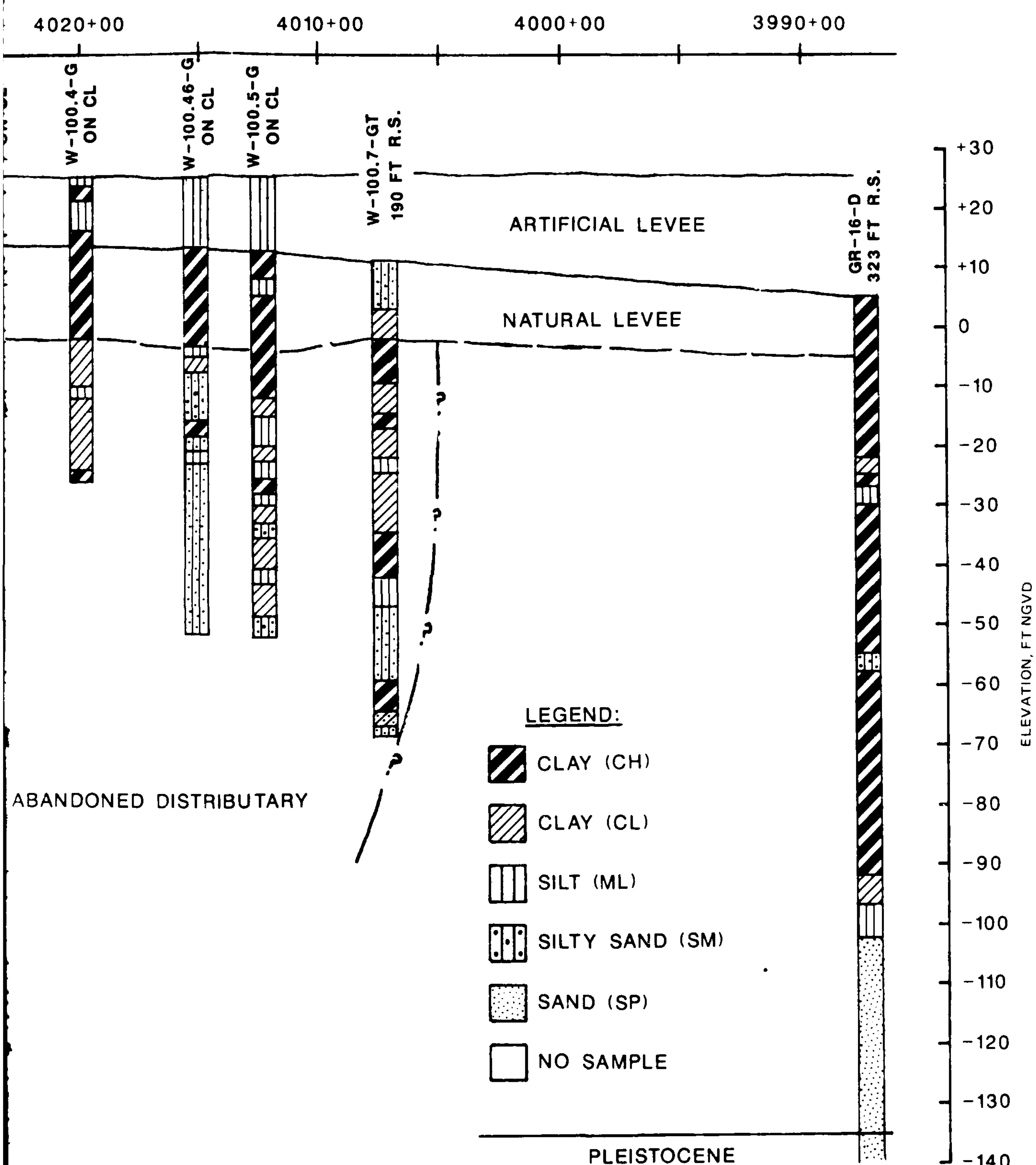


Figure 9. Soil profile along the bank reach containing the Celotex failure site

1

2



4020+00
4010+00
4000+00
3990+00
W-100.4-G ON CL
W-100.46-G ON CL
W-100.5-G ON CL
W-100.7-GT 190 FT R.S.
GR-16-D 323 FT R.S.
ARTIFICIAL LEVEE
NATURAL LEVEE
ABANDONED DISTRIBUTARY
PLEISTOCENE
LEGEND:
CLAY (CH)
CLAY (CL)
SILT (ML)
SILTY SAND (SM)
SAND (SP)
NO SAMPLE
ELEVATION, FT NGVD
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140

g the

2

3

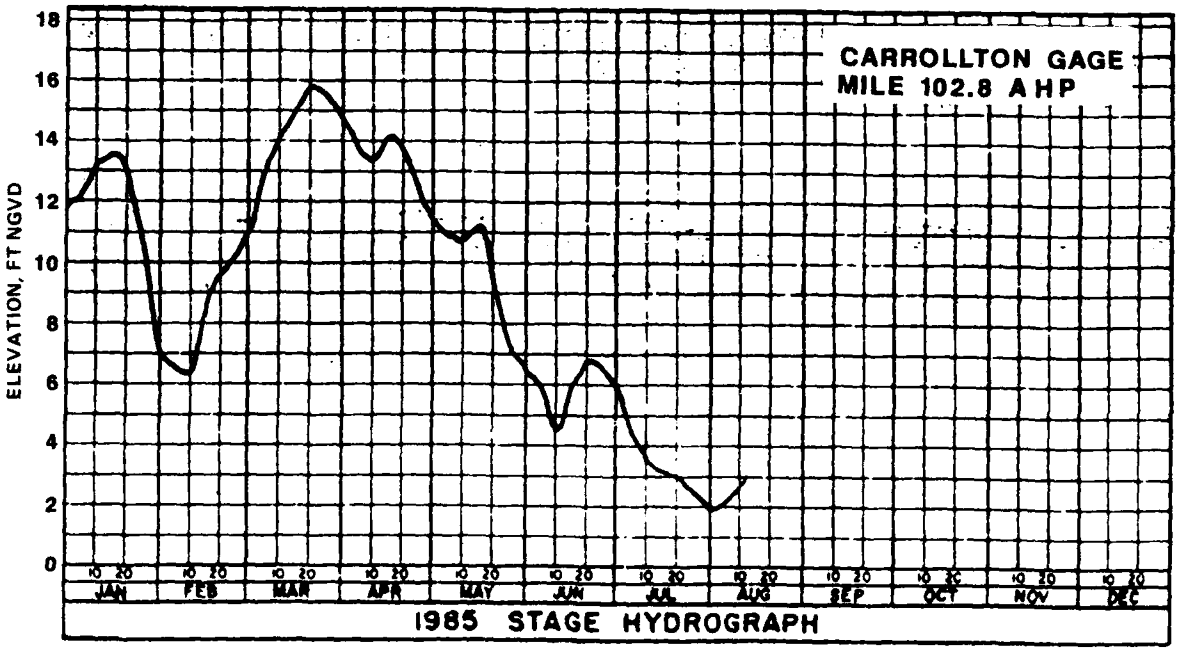


Figure 10. 1985 Mississippi River stage through the period of the Celotex failure

"oversteepened" slope in the sands and instigated the failure. After failure, evidence of the trench is not seen until a point about 700 ft upstream of range U-19, i.e., at revetment range U-24. Taking extremely rough 1984 dimensions of the trench cross section below el -80 over that 700 ft yields a volume of about 150,000 cu yds. Since the failure volume approached 300,000 cu yds, it is feasible that failure debris had such mass and momentum that it filled the trench in the upstream direction against the low flow current of the river. Additional evidence that the failure was initiated about revetment range U-19 is shown in Figure 5 wherein the typical narrow riverward neck is directed at that range. The orientation of the failure in that plan view also clearly implies an outflow of debris in a slightly upstream direction. On 10 November 1985, immediately before completion of repair of the batture and levee, a side-scanning sonar survey was run "looking" at the subaqueous portion of a reach of the riverbank and riverbed including the failure site. The lower portion of the survey image of Figure 11 is a plan view of the bank and river bottom beneath and to either side of the moving survey vessel. The image also indicates the upstream outflow of failure debris. The upper portion of Figure 11 was produced simultaneously with the side-scan image and is a continuous sonar depth sounding directly beneath the vessel

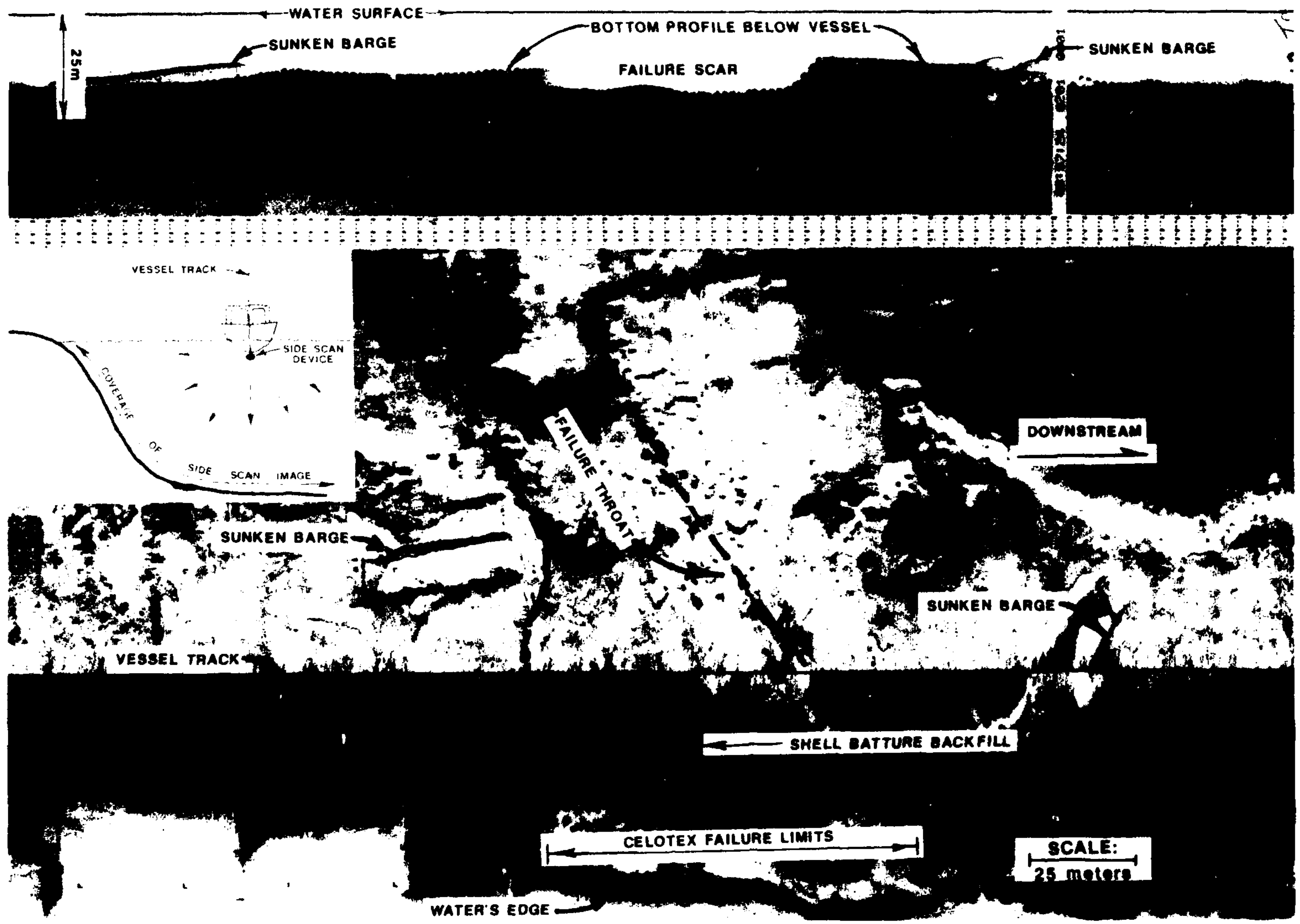


Figure 11. Side-scan sonar image of the Celotex failure reach

track including sub-bottom reflections. The survey also revealed two sunken barges lying on the slope of the bank on either side of the failure neck location. There is no way to know if those objects played a role in the failure. There is no knowledge as to how long they have been there.

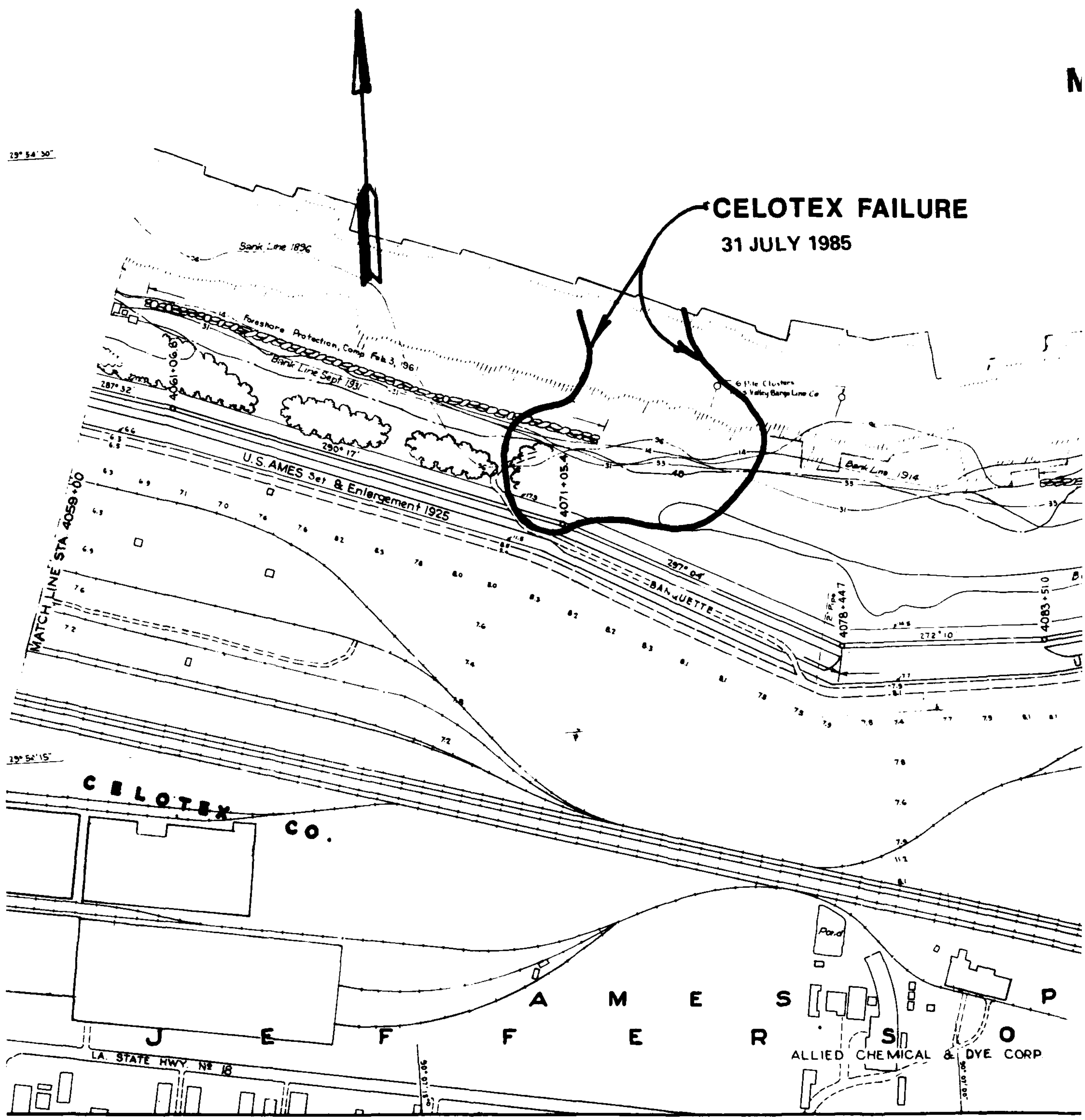
14. The only eye witness to the failure was the tugboat operator who alerted the NOD Operations Division. The only comment the author has heard as to what he described was that the bank went in all at once. Considering that it was during darkness, it is possible that his attention (and lights of his boat) was not directed to the bank until significant mass moved, and sound and water disturbance alerted him. He apparently did not remain to observe closely for a long period of time. His account leaves little to go on. It is known, as stated previously, that batture loss continued up to around 6 a.m.

15. In studying the plan and sections of Figures 5 and 6, respectively, the author conjectures as to a possible sequence of events. From the plan view of Figure 5, the failure has the appearance of dual lobes with a main body of the more symmetrical nature of a flow slide and a lobe in the landward, upstream portion (upper right portion of the plan view) which represents the involvement of the levee section and has the U-shape of a typical shear failure. A line of borings was logically taken straight out riverward from the center of the levee slide between revetment ranges U-18 and U-19 to investigate the presence of overburden material remaining in the failure scar. Those borings coupled with the Fathometer surveys of ranges U-18 and U-19 indicate that a narrow trench considerably deeper than the remainder of the failure existed along the line of borings. It would appear likely that the overburden material encountered lay only in that trench as indicated in the section of Figure 6. The other evidence of probable overburden remaining in the scar is the mound shown in Figures 5 and 6 between revetment ranges U-17 and U-18 which may have been a top stratum chunk which broke away but was not carried out into the river. From the section of Figure 6 for range U-17, it is shown that the "depression" to the riverward side of the chunk is in conformance with the general "bowl" elevation of the failure. The computer images of Figures 7 and 8 make this more evident. It is feasible that, at some time during the progress of the main failure, scour conditions also triggered a deeper additional outflowing which may be evidenced by the trench between ranges U-18 and U-19. That secondary flow may have produced instability in the top stratum and levee resulting in a shear failure and the movement

of debris into the trench where it was found by the borings. Given the limited survey data available to construct the contour picture, it appears that the mass shear slide possibly corresponding to the secondary lobe of the failure which involved the levee was at the overburden/sand contact near el 10. Other observations from the Celotex failure will be discussed in support of the levee safety flow slide monitoring system in the next part of this report.

Ramifications of the Celotex Failure

16. The history of the bank line along Greenville Bend revetment reach is shown in Figure 12 (file map, New Orleans District). The bank line in 1949 was determined from aerial photos. Earlier bank lines were established by ground surveys. The most apparent observation is that a major bank failure area existed in 1896 precisely at the Celotex location. In addition, looking downstream, other scallops are seen in the bank line over the years. In 1901, 1909, and 1922, setbacks were constructed in front of Amesville, LA, and the old General Alcohol Co. indicating the severity of bank losses during those times. A major failure highly likely to have been a flow slide because of the proportions of the batture loss is indicated in the 1900 bank line in front of the alcohol company complex. The 1973-1975 Mississippi River hydrographic survey shows a scour pool at this location. There is reason to believe that the bank loss patterns indicated by the old bank line data can be expected in the future all along the abandoned channel/point bar reach. The aerial photographs given as Figure 3 were taken in 1977 during an extremely low water period. Although small and difficult to see in the photographs, a scallop did exist at the Celotex failure location at that time. Other larger scallops are evident in Figure 3 in the downstream direction in various places in the point bar deposit. Of particular concern to the author is the very sharply defined scallop seen in the photograph just in front of the down stream end of the long, narrow complex of the Johns-Manville Co. (upper center of photo). The location corresponds to revetment ranges D-2 to D-3. Given the much smaller scallop preexistent at the Celotex site, this larger scallop demands special attention since the overburden is very thin, and no more batture than at Celotex protects the levee.


CELOTEX FAILURE
31 JULY 1985
Bank Line 1896
Foreshore Protection, Comp Feb 3, 1961
Bank Line Sept 1931
Bank Line 1914
U.S. AMES Set & Enlargement 1925
BANQUETTE
MATCH LINE STA 4058+00
4061+06.8
4071+05.4
4078+447
4083+510
CELOTEX CO.
AMES P
JEFFERSON
ALLIED CHEMICAL & DYE CORP
LA. STATE HWY. Nº 18
Pond
29° 54' 30"
29° 54' 15"

Figu

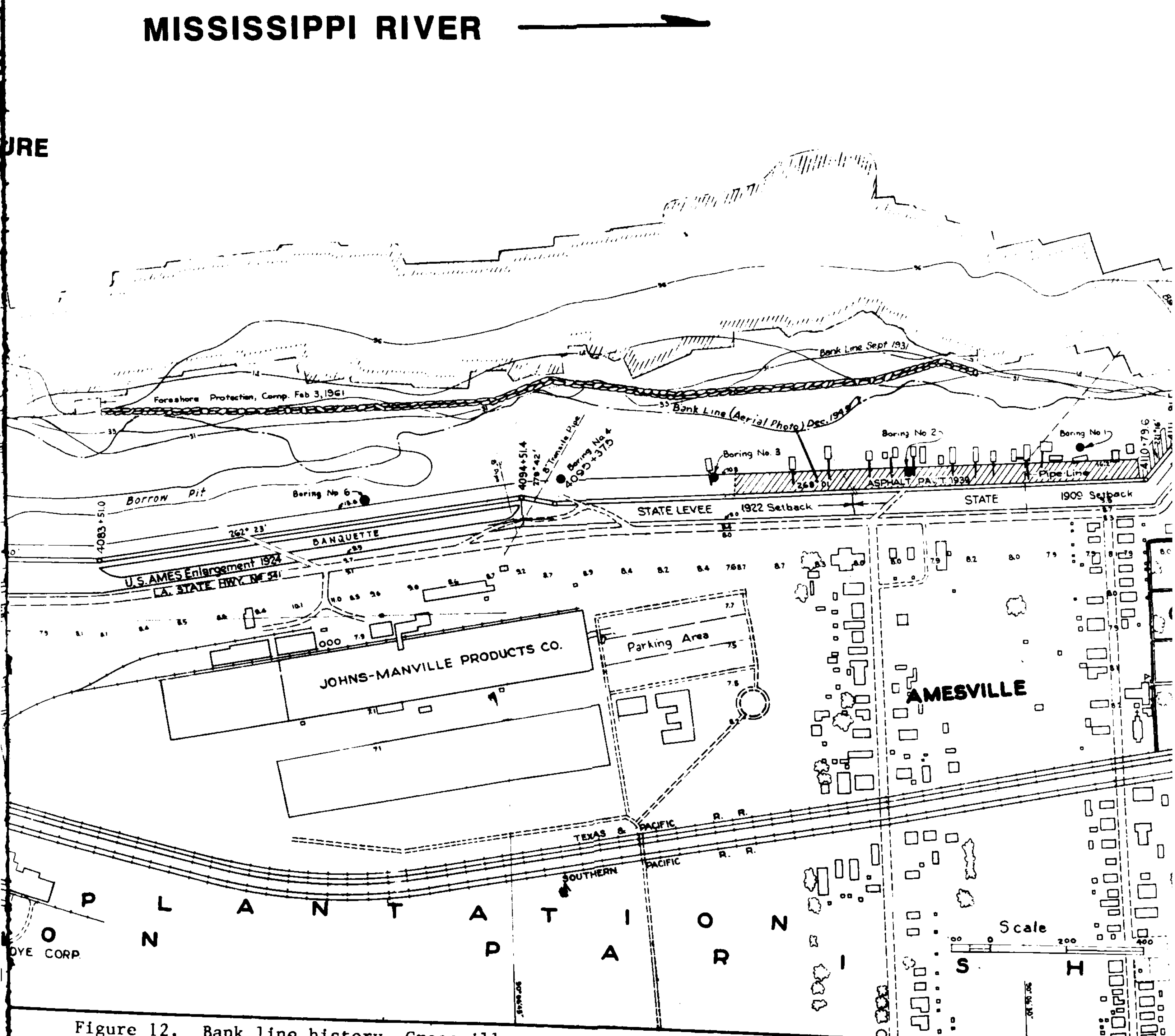
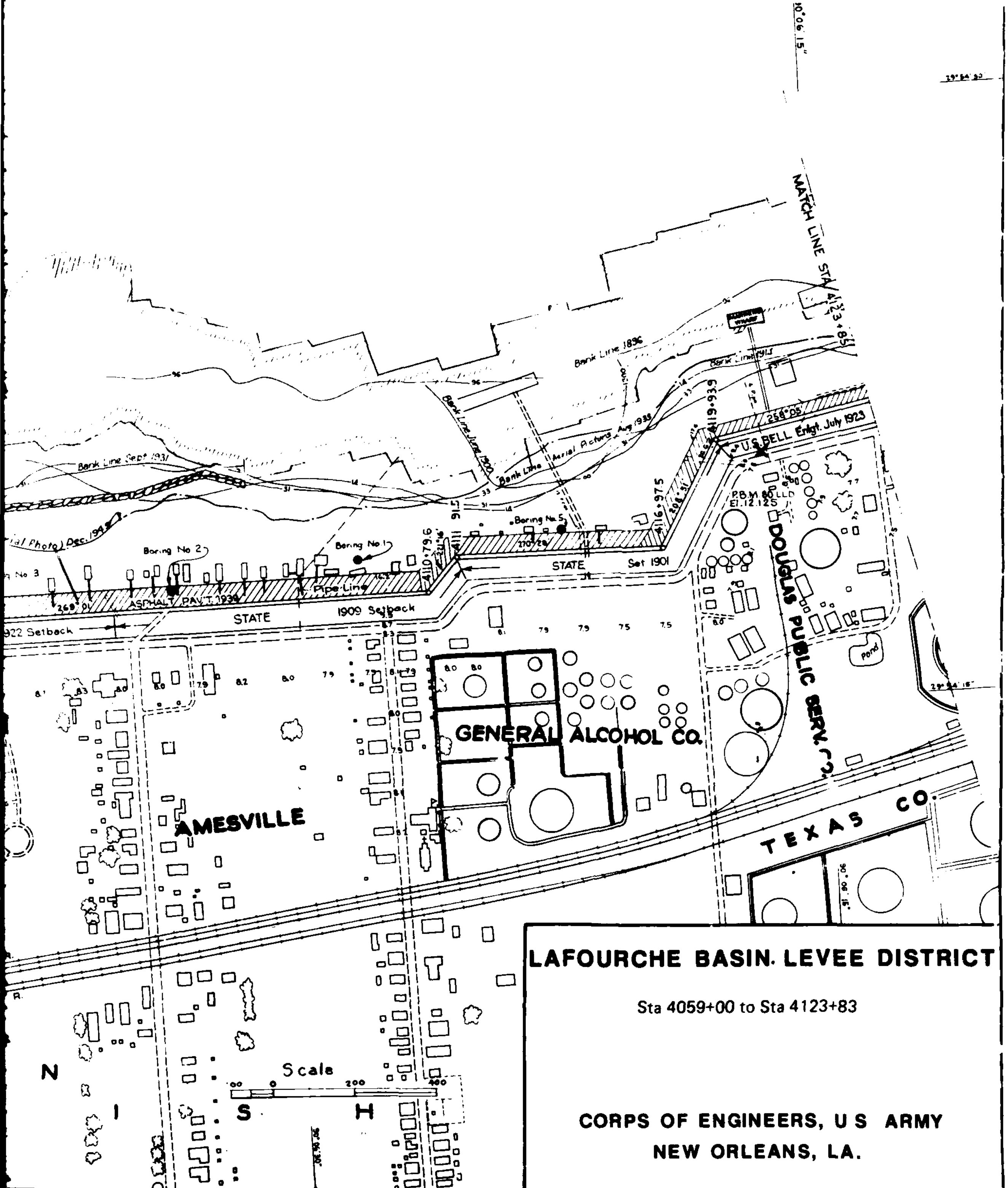


Figure 12. Bank line history, Greenville revetment reach

2


MATCH LINE STA 4123+85
Bank Line 1896
Bank Line Sept. 1931
U.S. BELL Enlgt. July 1923
Boring No. 5
Boring No. 1
Boring No. 2
Pipe Line
ASPHALT PAVT. 1936
STATE
Set 1901
1909 Setback
1922 Setback
P.B.M.
El. 12.125
DOUGLAS PUBLIC SERV. CO.
GENERAL ALCOHOL CO.
AMESVILLE
TEXAS CO.
pond
Scale
N
I
S
H
LAFOURCHE BASIN LEVEE DISTRICT
Sta 4059+00 to Sta 4123+83
CORPS OF ENGINEERS, U S ARMY
NEW ORLEANS, LA.

2

4

3

17. The historical migration of the Greenville Bend "permanent"scour pool is evident in Figure 13 where it is shown that the pool has been growing in length both upstream and downstream and moving in a southeasterly direction. The 1973-1975 hydrographic survey placed the downstream end of the pool based on el -100 at revetment range U-24. The previous discussion suggested that the pool in 1984 extended downstream close to range U-18 an additional 800 ft. The pool migration portends increasing attack along the Greenville revetment reach in the downstream direction. Particular watchfulness appears to be warranted from revetment range U-30 to D-15.

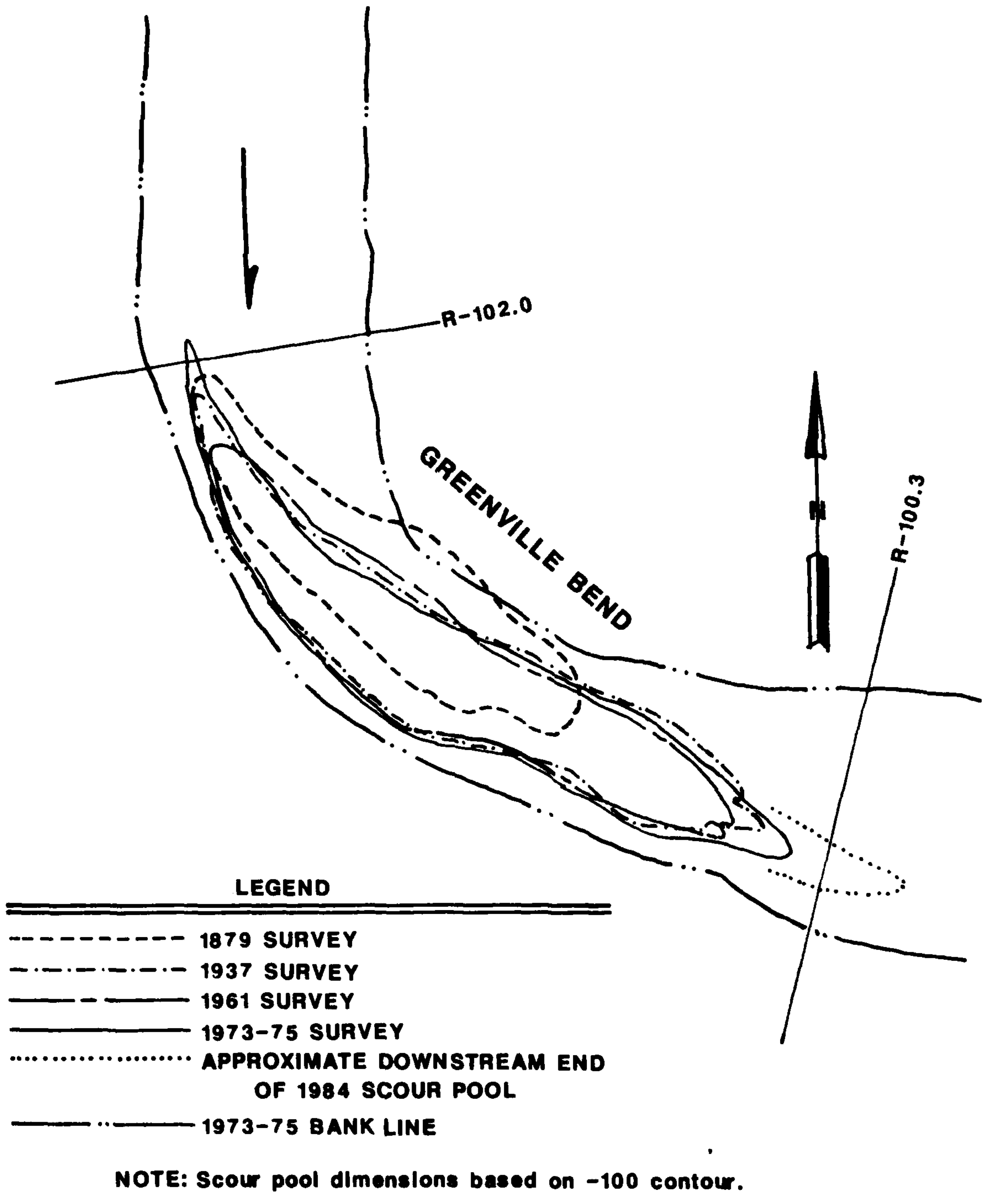


Figure 13. Historic trend in movement of permanent scour pool, Greenville Bend, Mississippi River

PART III: THE FLOW SLIDE LEVEE SAFETY MONITORING SYSTEM

Background

18. Among the accomplishments described in the last report to LMVD (Torrey, Dunbar, and Peterson 1986) was a theoretical analysis by Dr. Christopher Padfield of the retrogressive mechanism in dilatant (dense) sands. Out of the numerical treatment emerged the concept of the runout angle which defines the final geometry of a flow slide assuming no excess removal of soil by scour. Figure 14 illustrates the retrogression mechanism. Two most important questions relative to the runout angle concept are:

a. Is there empirical evidence that the concept is valid?

b. If there is positive evidence, can the runout angle be estimated as a single average value, or is it a significantly wide-ranging variable for flow slides below Baton Rouge?

Empirical Evidence of a Runout Angle

19. For several years the author was involved in the Potamology Investigation entitled, "Verification of Empirical Method for Determining Riverbank Stability," which consisted of studying the average of 25 or so flow slides observed annually in revetted banks of the river primarily between Memphis, TN, and Natchez, MS. The objective of these studies was to verify criteria for determining susceptibility or stability of a site with respect to flow failure. The reader is referred to Gann (1981) for the last report of a long series (17 reports dating from 1956) which describes the criteria. The decision was made after that report was published that the criteria had been validated, and there was no need to continue expending effort and funds in that direction. Out of all those studies and other earlier studies, it was seen that flow failures tended to exhibit trends in their geometry. Indeed, as is shown in Figure 15 taken from Potamology Investigations Report 12-5 (Hvorslev 1956), there were attempts to establish those trends. What is not evident from Figure 15 is that there also was a strong trend between depth of the Zone A/Zone B interface and depth of failure since so many, but not all, failures appeared to have been initiated near the Zone A/Zone B interface. Evidence of this is given in Figure 16 also taken from Potamology Investigations

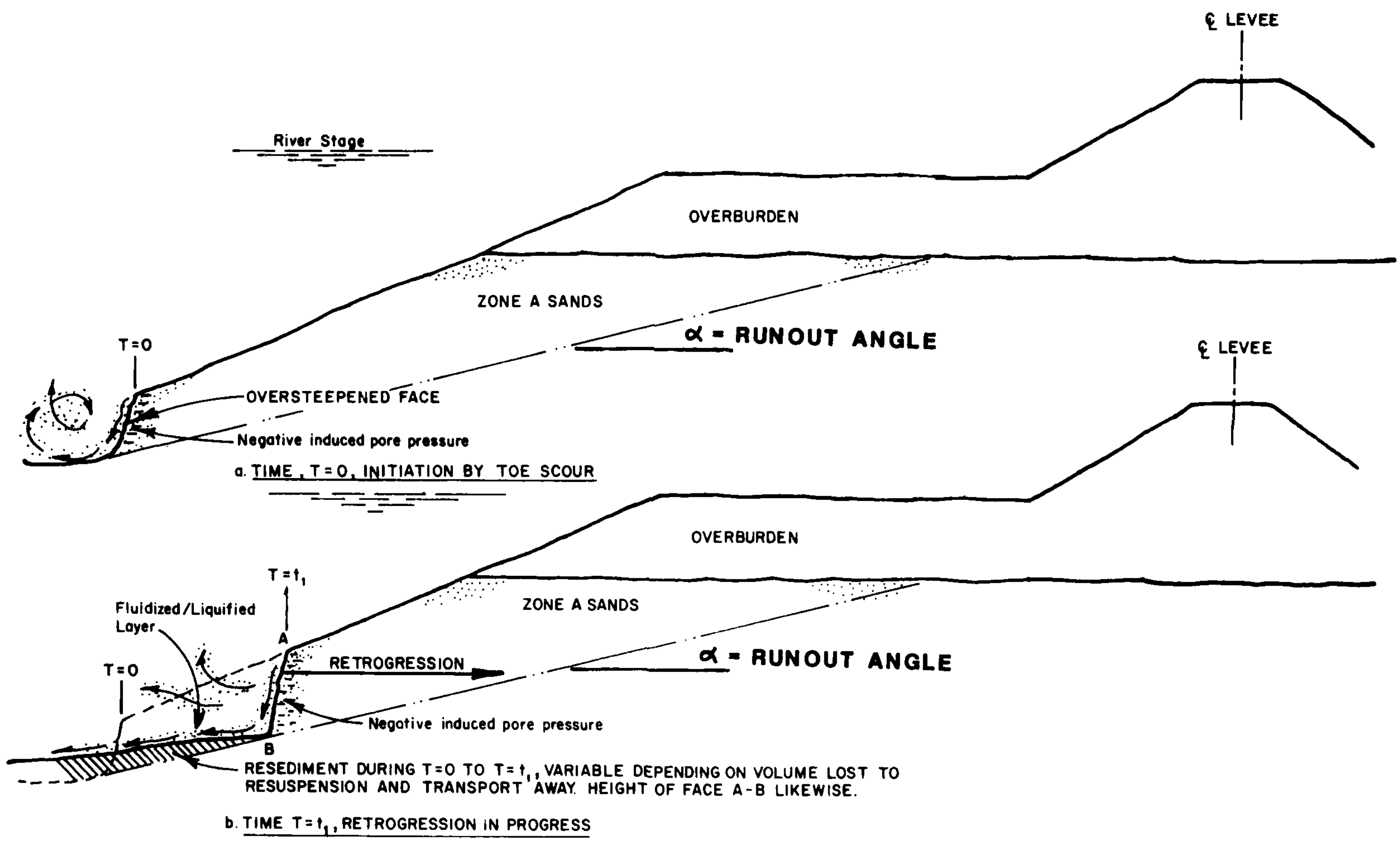
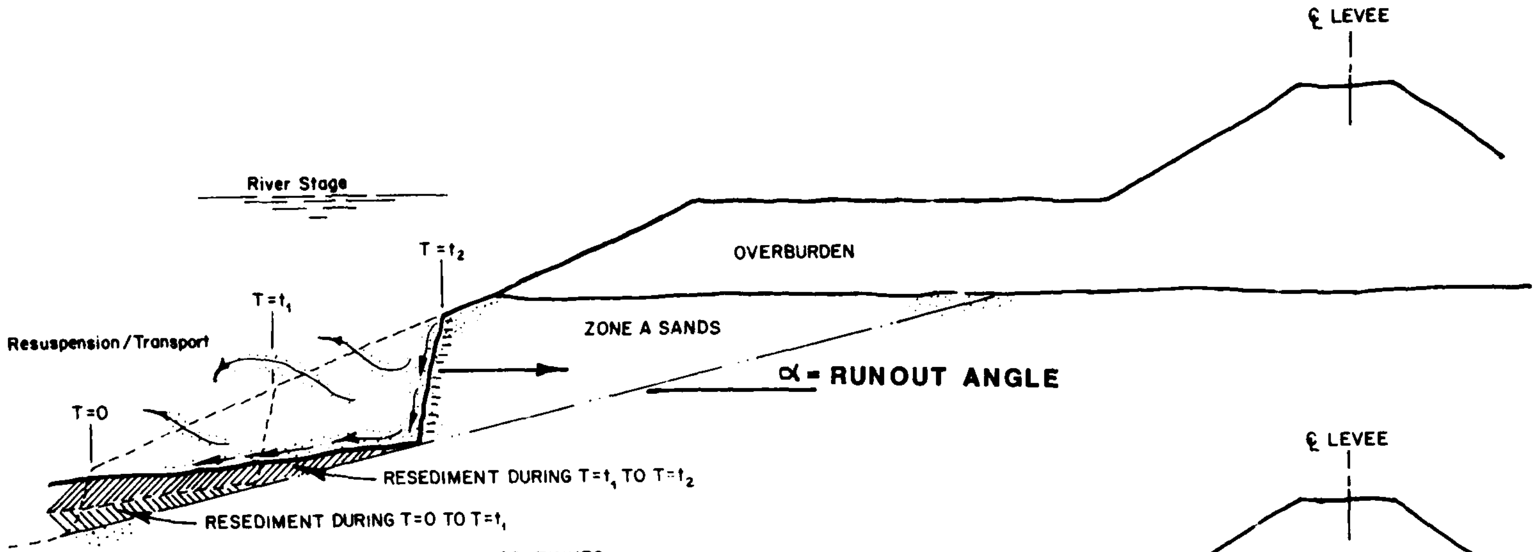
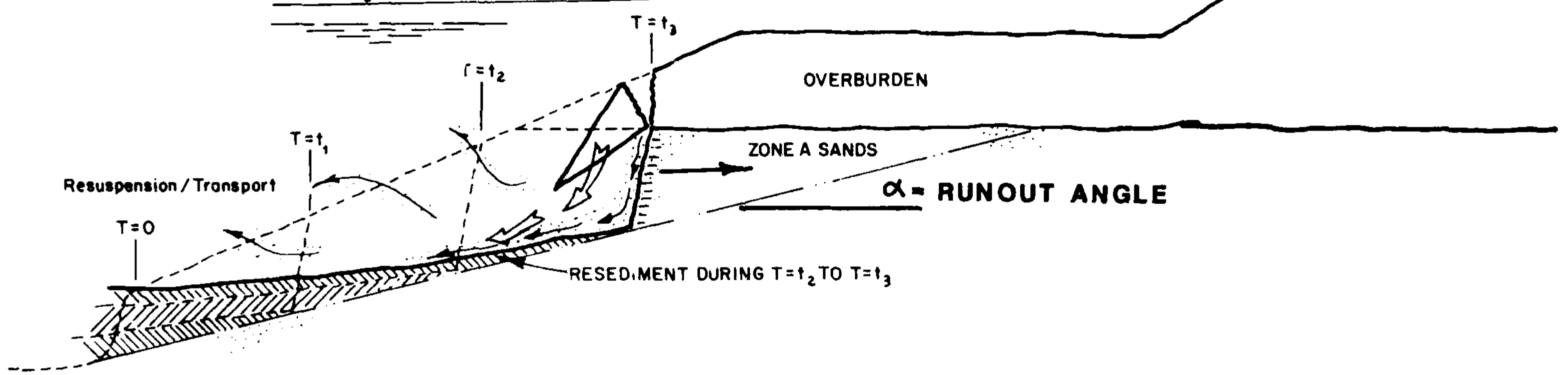


Figure 14. Sequential stages of retrogressive failure of a flow slide in dilatant sands (Sheet 1 of 3)



c. TIME $T=t_2$ RETROGRESSION CONTINUES



d. TIME $T=t_3$ OVERBURDEN UNDERCUT BEGINS, BLOCKS FAIL AND RIDE OUT UPON FLUIDIZED/LIQUIFIED LAYER

Figure 14. (Sheet 2 of 3)

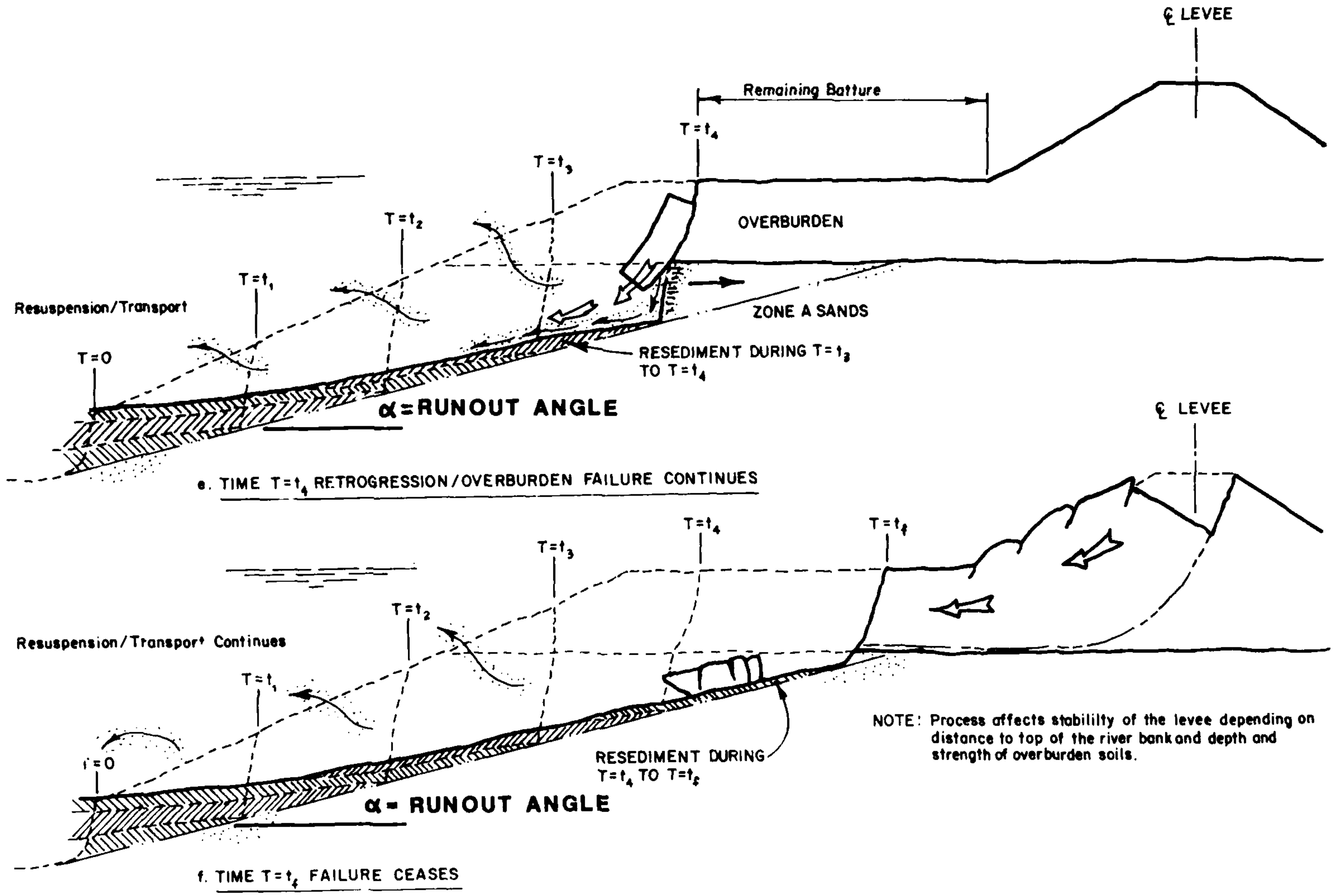


Figure 14. (Sheet 3 of 3)

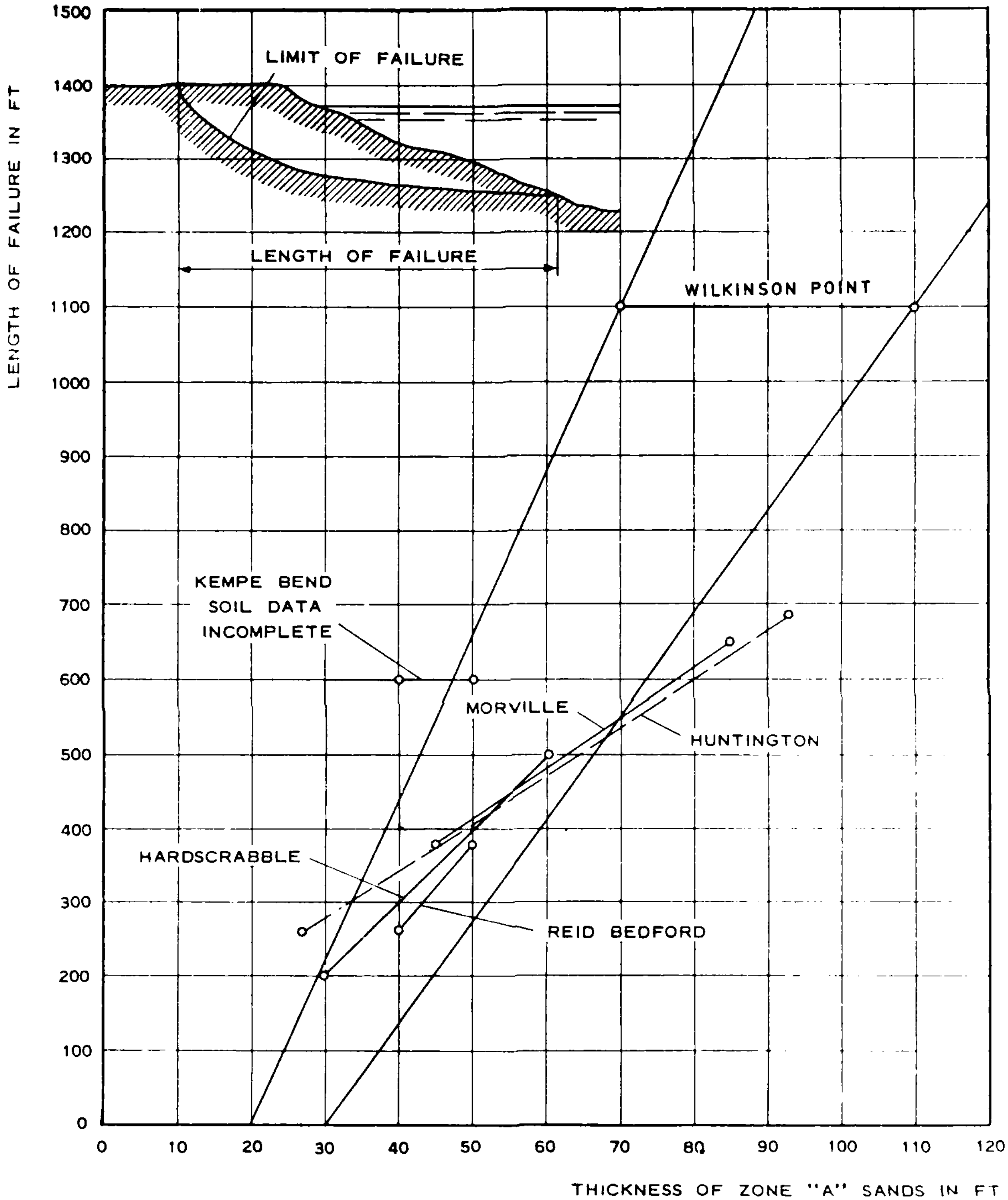
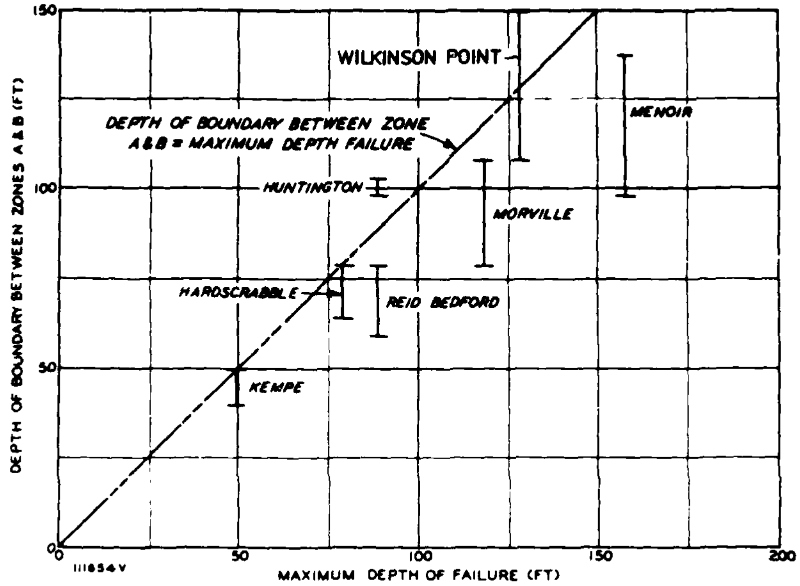
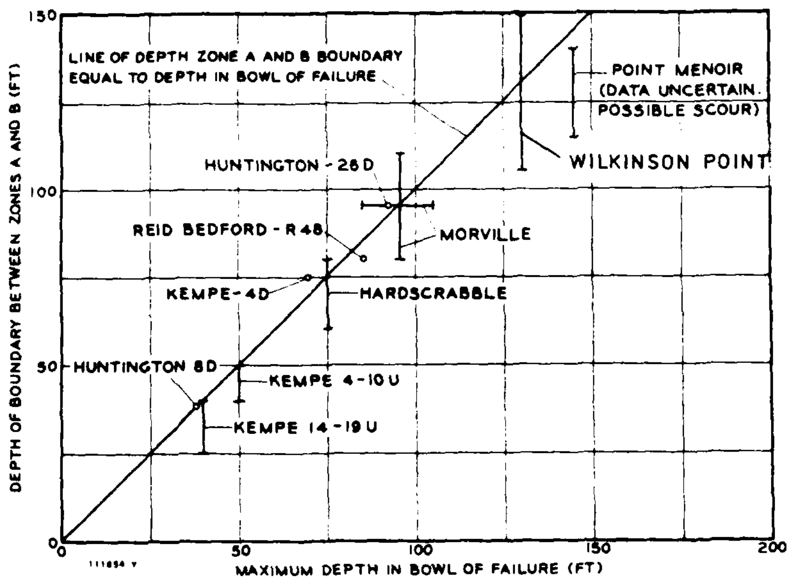


Figure 15. Length of failure versus thickness of Zone A sands (from Potamology Investigations Report 12-5)



a. Ratio of depth of failure to depth of boundary between Zone A and Zone B sands



b. Depth of failure and depth of Zones A and B boundary for individual failures

Figure 16. Depth of failure versus depth to Zones A and B boundary (from Potamology Investigations Report 12-5)

Report 12-5. Where Figure 16 shows that some failures extended into Zone B sands, two directions of reasoning arise:

a. Scour conditions within the failures removed the additional sand below the Zone A/Zone B interface.

b. The retrogressive mechanism also occurs in Zone B sands.

It is obvious that severe scour conditions which initiated the failure might continue at work and would affect the ultimate volume of material lost. Large eddies with significant circulation velocities have been observed within failure areas (by others in the past and by the author) as would be expected as a natural hydraulic result of a localized scallop-shaped bank loss. It may be that the typical "bowl" of a flow failure is reflective of that eddy sweeping action. With respect to retrogression in Zone B sands, Padfield's (1978) original theoretical treatment (also presented in Report 1 by Torrey, Dunbar, and Peterson 1988) does not exclude the possibility that Zone B gradations can exhibit sustained retrogression. Permeability directly affects the rate of retrogression, and grain-size distribution affects the theoretical value of the runout angle. Very permeable and coarse material would theoretically yield such a large runout angle so that retrogression would not "eat" very far into the bank. The current studies of the retrogression mechanism will address these parameter effects among several others. For all that is known at this time, these studies may eventually explain the empirical gradation criteria. The very establishment of the original Zone A versus Zone B gradation ranges and the subsequent modification of those ranges were judgments based on predominant (not exclusive) observations as to what gradations seemed to be involved in flow failures. There may have been factors other than gradation at work such as trends in depth of river attack which exerted a major influence on the designation of Zone A versus Zone B rather than the actual flow slide mechanism. However, there is evidence that the geometry of flow slides with respect to depth and length exhibits trends. In addition, the thickness of Zone A sand plotted in Figure 15 can also be roughly taken on the basis of Figure 16 to correspond to the thickness of sand involved in failure. There appears to be reason to pursue the concept of runout angle.

20. Now the quandary arises as to whether or not the runout angle varies significantly over the range in gradation of Zone A sands. It is acceptable to disregard the question as to whether or not Zone B sands can be involved in the retrogression for the reach of river below Baton Rouge because

Zone A sands are typically so thick that observed flood period failures have not involved Zone B. For the Marchand type failure involving deep sands, the issue is not that clear cut because the time has not yet been found to systematically classify those sands. This is yet to be done. With respect to the variability of the runout angle over the range in Zone A gradations, the current state of the art relative to parametric effects on the theoretical failure mechanism is limiting along with the fact that the empirical data base will have to be expanded to arrive at confident conclusions. This is why it is important that all future flow slides below Baton Rouge be carefully surveyed and preexisting scour conditions be known for each. If it is not possible to identify a consistent value of the runout angle, at least for bank reaches, the usefulness of the concept in predicting potential dimensions of a flow failure becomes questionable. However, in the paragraph to follow, it is shown to be possible to address the issue empirically and, fortunately, to make a substantial preliminary judgment.

21. The data of Figure 15 are plotted with data from the 1973 flow slides below Baton Rouge and the Celotex data in Figure 17. The parameters plotted in Figure 17 are explained in the inset on the figure. In keeping with the mechanism of failure illustrated in Figure 14, the beta angle, β , of Figure 17 is the approximate average slope of the resedimented material after failure. Note that in order for this to be true, the failure slope in the overburden must be relatively vertical as has been observed to be generally the case. If no major scour develops within the failure which removes material in excess of that involved in the retrogression mechanism, β must be less than or equal to the runout angle. If the failure proceeded with just the perfect assistance of scour such that every grain of sand raining off the retrogressing face and every piece of overburden were removed from the scar, then β would equal α . In that special case, there would have been no resedimentation of any of the sand raining off the retrogressing face. It can be deduced from the sections of typical failures of record that with few exceptions some resedimentation does occur, and β is less than α . This is because projections of the average β just do not conform to the concept of the scour pool/trench as the initiation point of failure. In other words, the projection of the average bottom slope of a typical failure would intersect the river bottom well out into the river and pass well above and beyond the scour pool/trench. The value of Figure 17 lies in the suggestion of a maximum

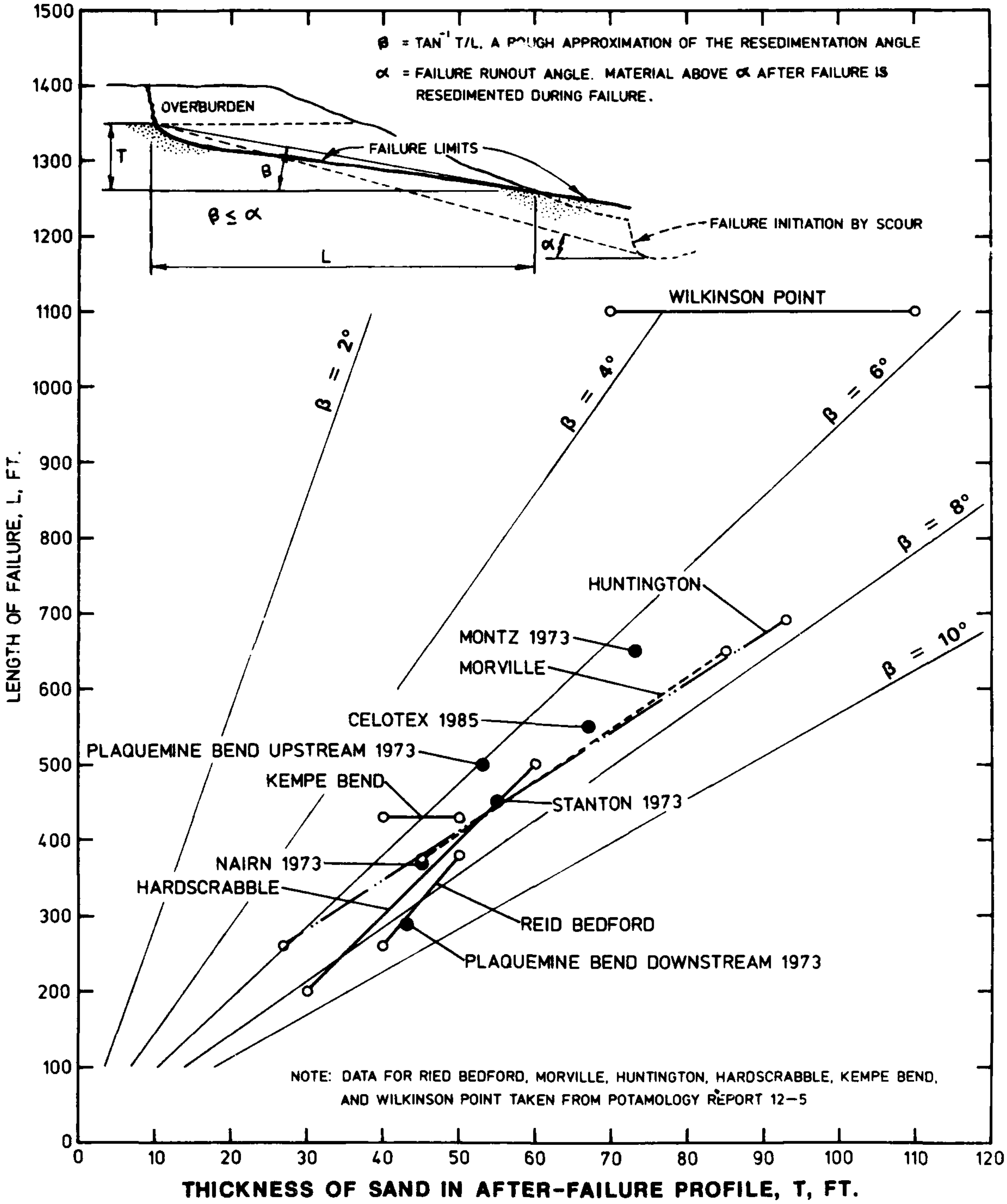


Figure 17. Estimation of a maximum value of runout angle α from empirical values of resedimentation angle β

value for β and, therefore, a possible maximum value for α. The author selects the maximum implied value of α from Figure 17 to be 9 or 10 deg, say 10 deg, taken from the initiating point of scour. This is a valuable implication. However, does that 10-deg runout angle represent a maximum of a wide-ranging variable, or can it be taken as a representative value for all failures below Baton Rouge? It would be logical that a representative value is feasible because the range in Zone A gradations is not a broad one.

22. Turning back to the sections of the Celotex failure of Figure 6, two important observations are as follows:

a. Assuming that the scour which triggered the failure in 1985 was similar to that seen in the 1984 survey at revetment range U-19, the projection of a 10-deg runout angle from that trench closely conforms to the extent of batture loss. It must be remembered that the runout angle is a sand failure parameter so that projection of the angle is up to the base of the overburden. A failure slope in the overburden can conservatively be taken as 45 deg, i.e., treating the overburden as a clay failing in unconsolidated, undrained shear (Q strength, Q = 0). This overburden failure slope will usually be conservative with respect to batture loss because it has been commonly observed that overburden scarps in flow slides are nearly vertical in a significant upper portion. There is no mystery behind the near vertical upper portion of overburden scarps because tension cracks of considerable depth would form as a section of overburden is undercut and cantilevered by the outflow of underlying sand. The thinner the overburden, the more likely the scarp will be near vertical. Secondary mass instability in the overburden is always possible depending on its strength profile and the presence of any bank loadings such as the levee.

b. The trench of the Celotex failure between revetment ranges U-18 and U-19 presents an intriguing possibility. A 10-deg runout angle also fits the average bottom slope of the trench. This may represent a "clean" runout as previously postulated during which there was resedimentation in the area of the scour which triggered it and some scour modification.

23. The opportunity has not yet arisen to go back into the records pertinent to past flow failures in a thorough manner to attempt to check "fit" of a 10-deg runout angle. This task will be attempted although it is probable that very little detailed data such as prefailure scour conditions or original revetment surveys of the scars will be available even in old records storage. The author is concerned that a cost/benefit problem may emerge.

24. It is possible herein to apply the 10-deg runout angle to the sections approximately through the center of the flow slides which occurred below Baton Rouge during the flood of 1973 just to see if the pictures appear

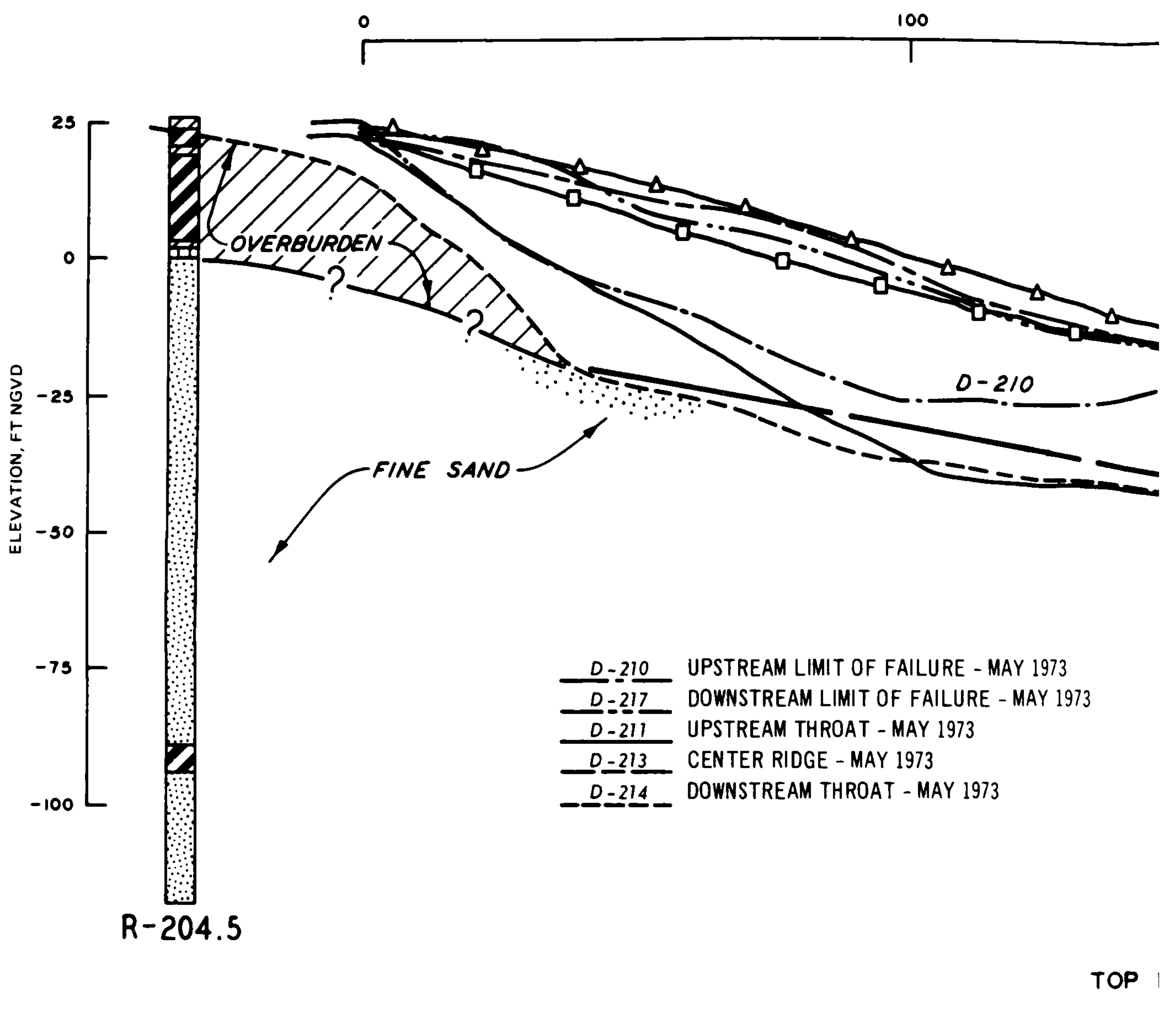
feasible. Those sections are for the failures at Plaquemine Bend, Montz, Stanton, and Nairn, LA, and are shown in Figures 18-22. They were taken from a report submitted to LMVD in 1976.* Placement of the 10-deg runout angle must be done in reverse on the sections, i.e., from the overburden/sand interface point downward because prefailure scour conditions are not available. In each case, it is seen that the 10-deg line very feasibly "fits" the sections. The key to the word "fits" is that any line much flatter would imply an initiation of the failures too far out in the river to conform to "permanent" scour pool positions. The fit to the Nairn failure (Figure 22) is particularly close right down to the probable riverward slide fill (resedimented during retrogression) as it was originally labeled on the drawing over 10 years ago. Another pertinent observation from these sections and the Celotex sections are the typical landward bowls of the failures where the central sections lie a little below the 10-deg projections. It was pointed out previously that the bowl is thought to be attributable to relatively gentle eddy scour which develops within the scar.

25. The readily available empirical evidence particularly pertinent to the river reach below Baton Rouge has been presented above in support of the concept of a runout angle and an apparent representative value of that angle of about 10 deg. The author believes that the evidence is sufficient to warrant proceeding with a monitoring system which assumes that the potential dimensions of a flow failure can be estimated using the projection of a 10-deg runout angle from the scour trench/pool. A warning reminder must be added to any suggestion that potential flow slide dimensions can be predicted. There is no way to predict batture losses resulting from either of the following:

- a. Severe scour may develop within the failure as it apparently did at Wilkinson Point, Point Menoir, and other cases indicated in Figure 16.
- b. Secondary retrogression may be initiated landward of the original bank line by localized scour within a developing or essentially terminated failure as was previously postulated for the Celotex site.

Considering these possibilities, if the potential dimensions of a failure predicted using the 10-deg runout angle yields a factor of safety for the levee

* V. H. Torrey, and W. E. Strohm. 1976. "Investigation of Liquefaction Susceptibility and Prevention of Flow Slides in Mississippi Riverbanks" (unpublished), US Army Engineer Waterways Experiment Station, Vicksburg, MS.



0
100
25
0
-25
-50
-75
-100
ELEVATION, FT NGVD
OVERBURDEN
FINE SAND
D-210
R-204.5
D-210 UPSTREAM LIMIT OF FAILURE - MAY 1973
D-217 DOWNSTREAM LIMIT OF FAILURE - MAY 1973
D-211 UPSTREAM THROAT - MAY 1973
D-213 CENTER RIDGE - MAY 1973
D-214 DOWNSTREAM THROAT - MAY 1973
TOP

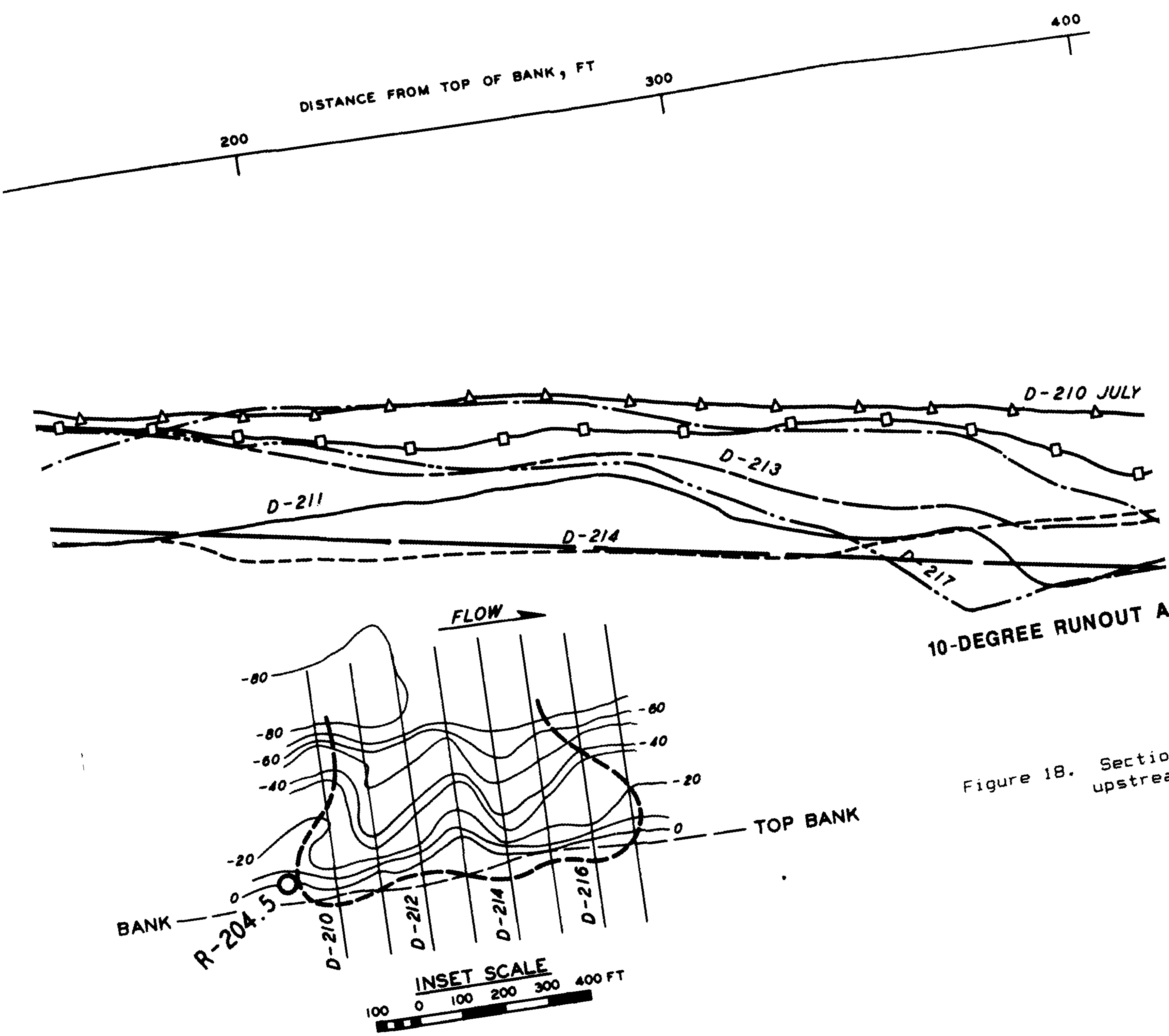


Figure 18. Sections
upstream

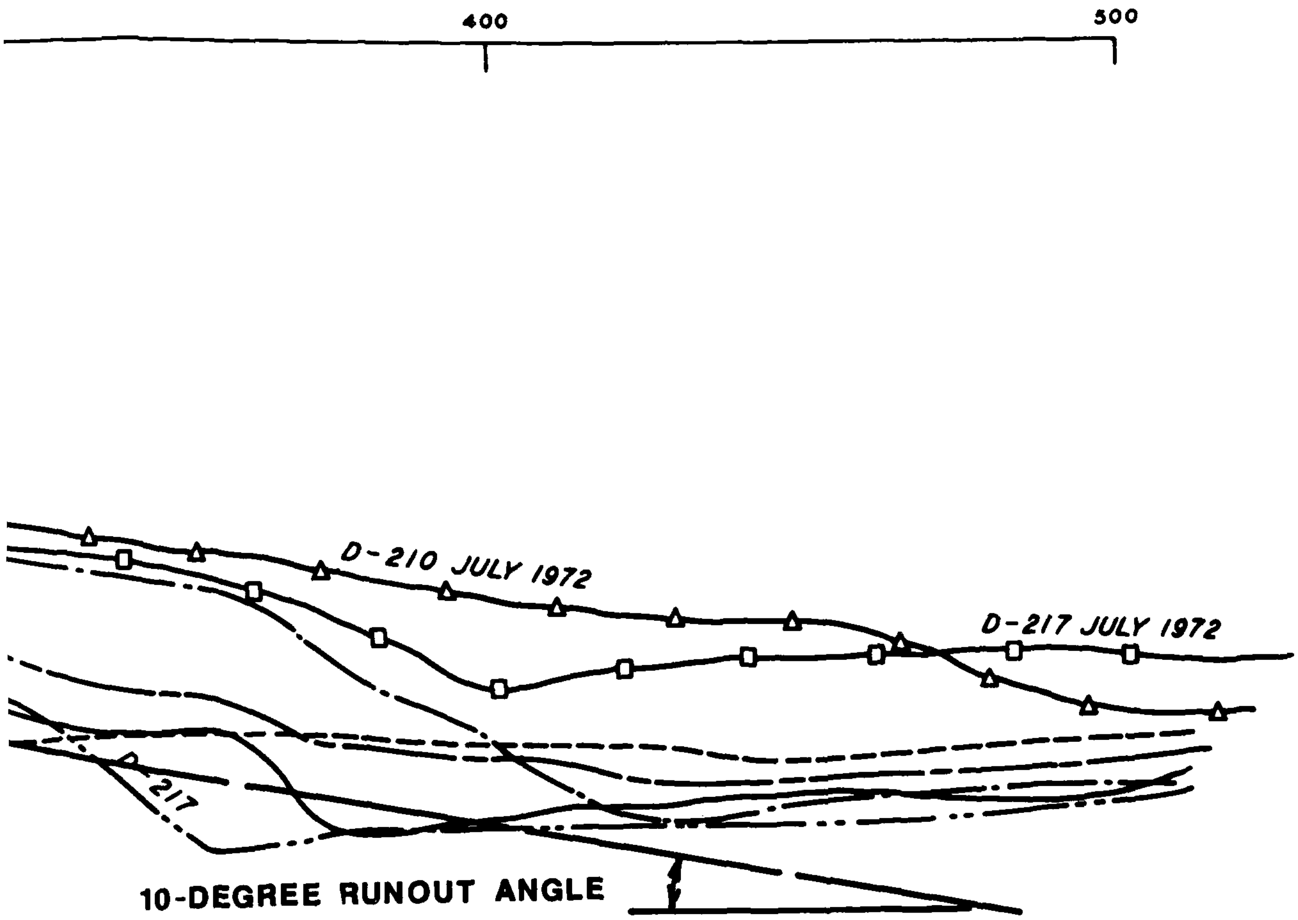
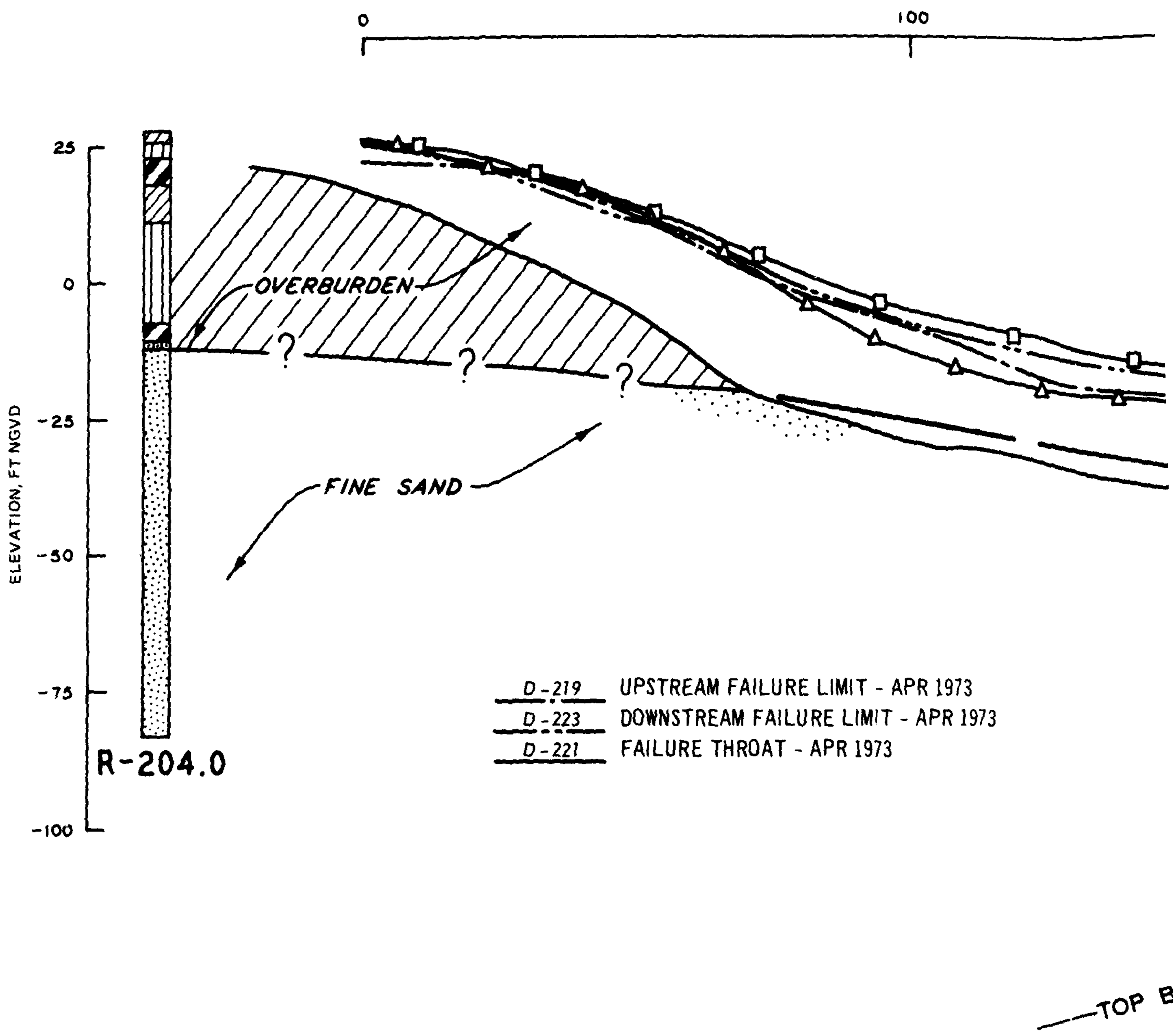
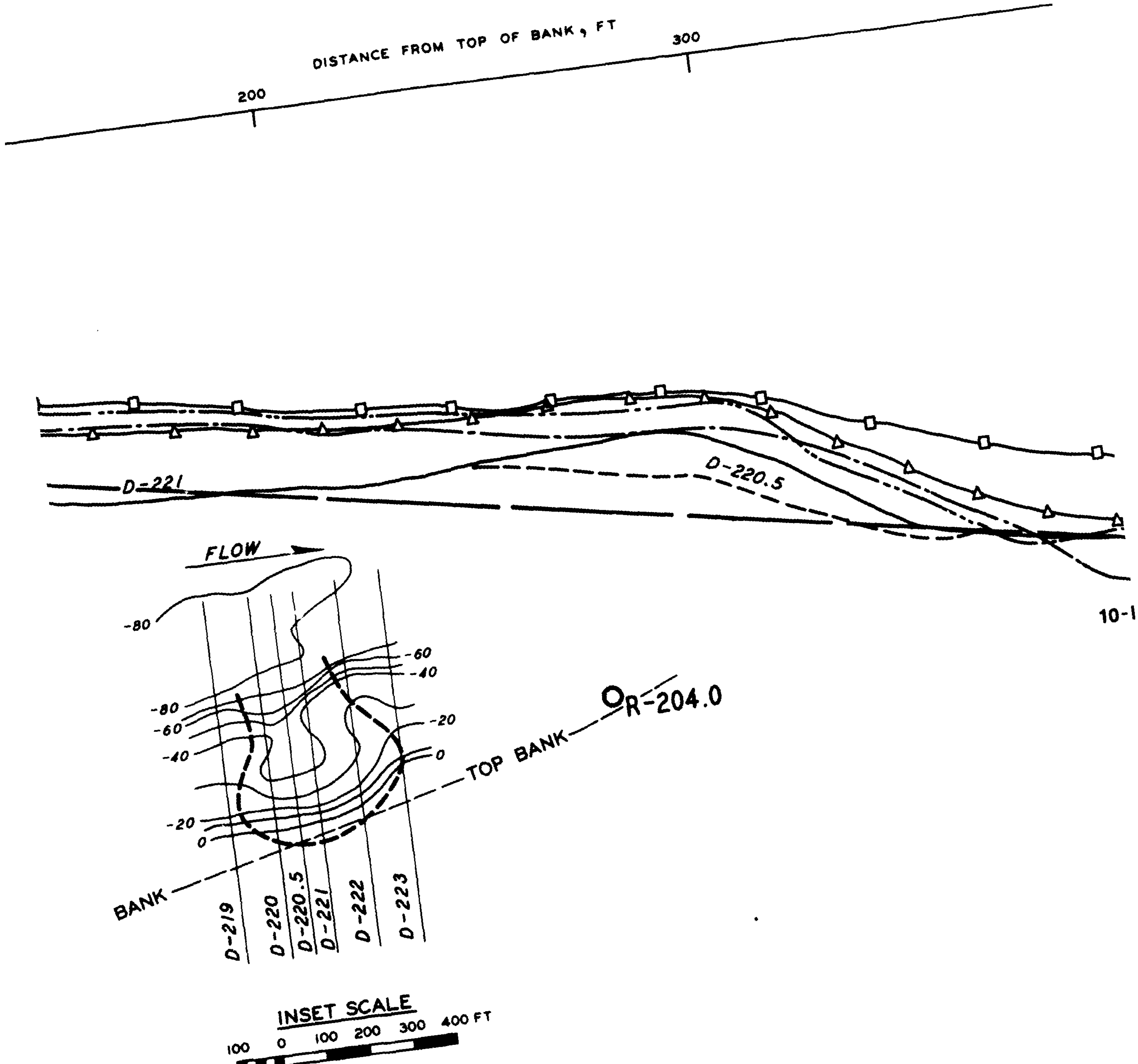


Figure 18. Sections perpendicular to the riverbank, 1973 upstream failure at Plaquemine Bend, LA.


0
100
25
0
-25
-50
-75
-100
ELEVATION, FT NGVD
OVERBURDEN
FINE SAND
R-204.0
D-219 UPSTREAM FAILURE LIMIT - APR 1973
D-223 DOWNSTREAM FAILURE LIMIT - APR 1973
D-221 FAILURE THROAT - APR 1973
TOP B


DISTANCE FROM TOP OF BANK, FT
200
300
D-221
D-220.5
FLOW
-80
-60
-40
-80
-60
-40
-20
0
-20
0
R-204.0
TOP BANK
BANK
D-219
D-220
D-220.5
D-221
D-222
D-223
INSET SCALE
100
0
100
200
300
400 FT

10-1

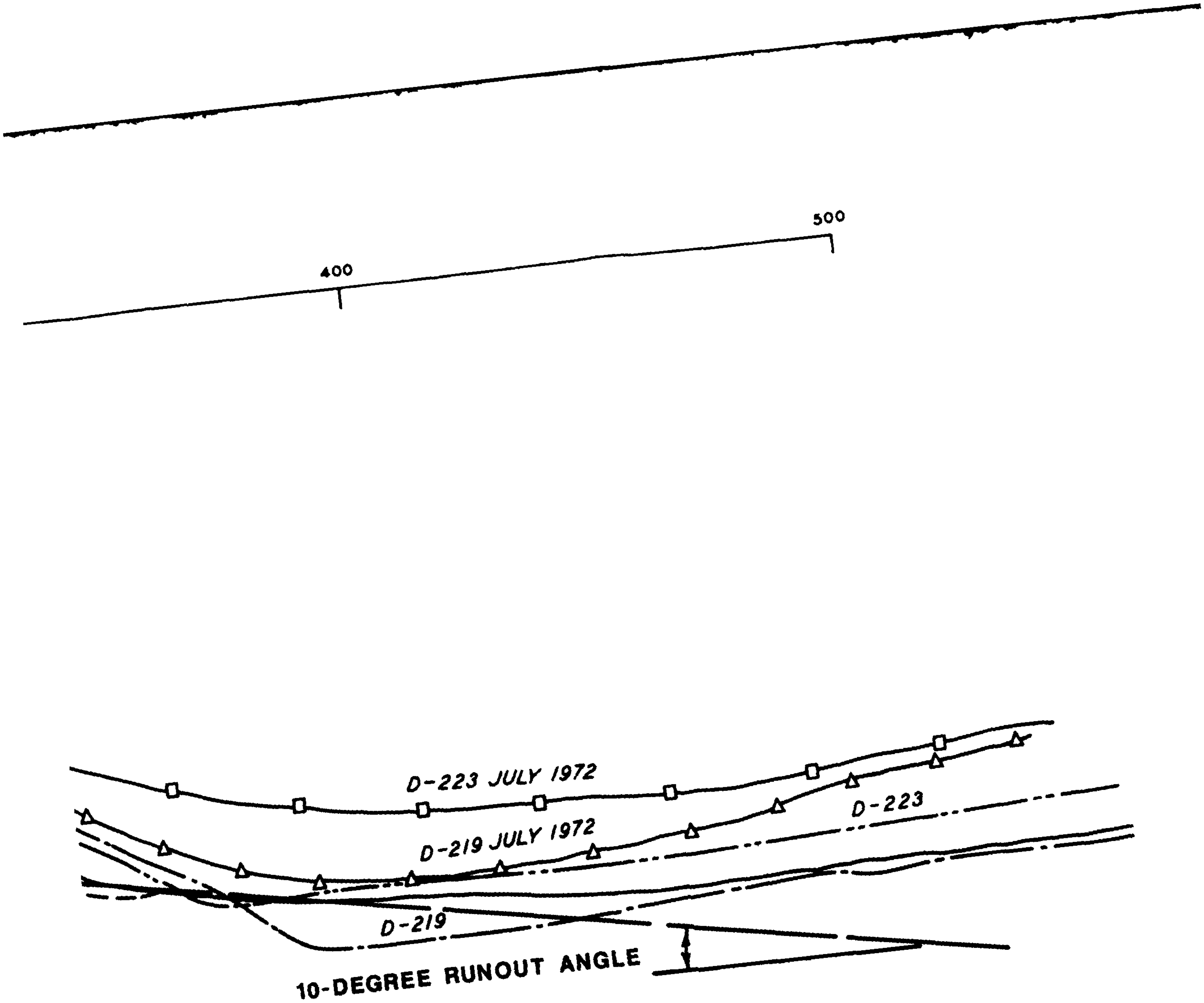
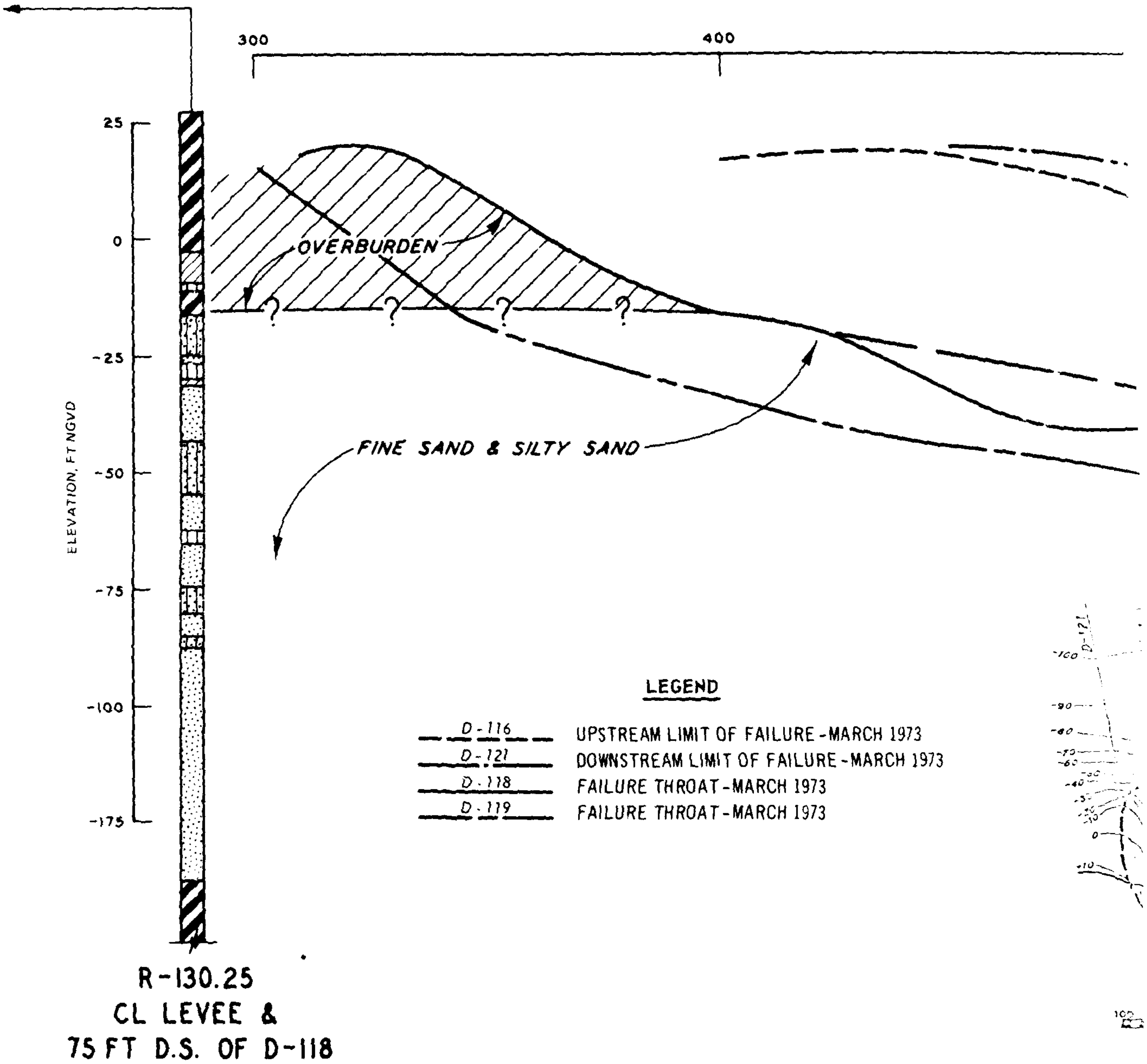
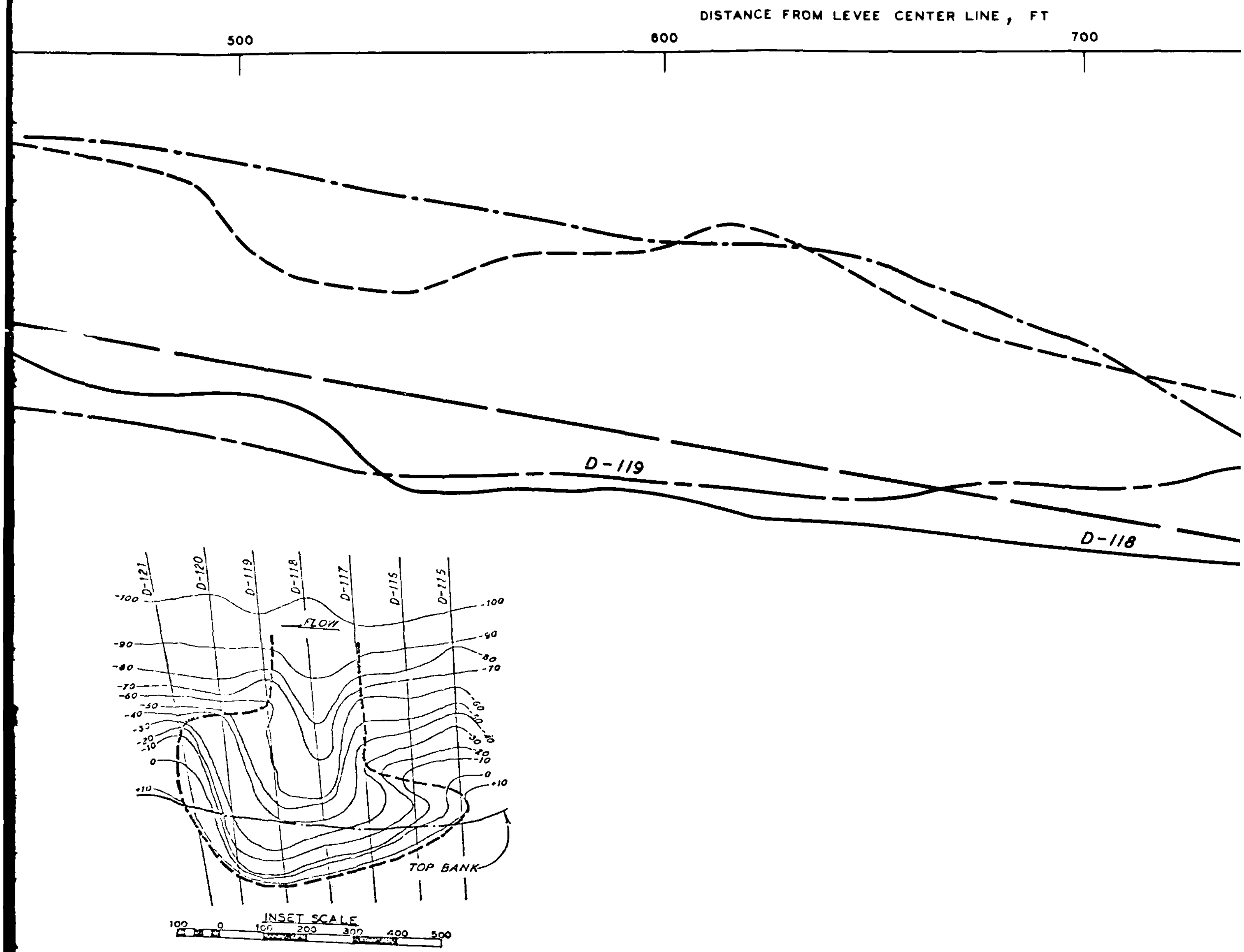


Figure 19. Sections perpendicular to the riverbank, 1973 downstream failure at Plaquemine Bend, LA.


300
400
25
0
-25
-50
-75
-100
-175
ELEVATION, FT NGVD
OVERBURDEN
FINE SAND & SILTY SAND
LEGEND
D-116 UPSTREAM LIMIT OF FAILURE-MARCH 1973
D-121 DOWNSTREAM LIMIT OF FAILURE-MARCH 1973
D-118 FAILURE THROAT-MARCH 1973
D-119 FAILURE THROAT-MARCH 1973
R-130.25
CL LEVEE &
75 FT D.S. OF D-118

1



DISTANCE FROM LEVEE CENTER LINE, FT
500
600
700
D-119
D-118
D-121
D-120
D-119
D-118
D-117
D-115
D-115
FLOW
TOP BANK
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
+10
INSET SCALE
100
0
100
200
300
400
500

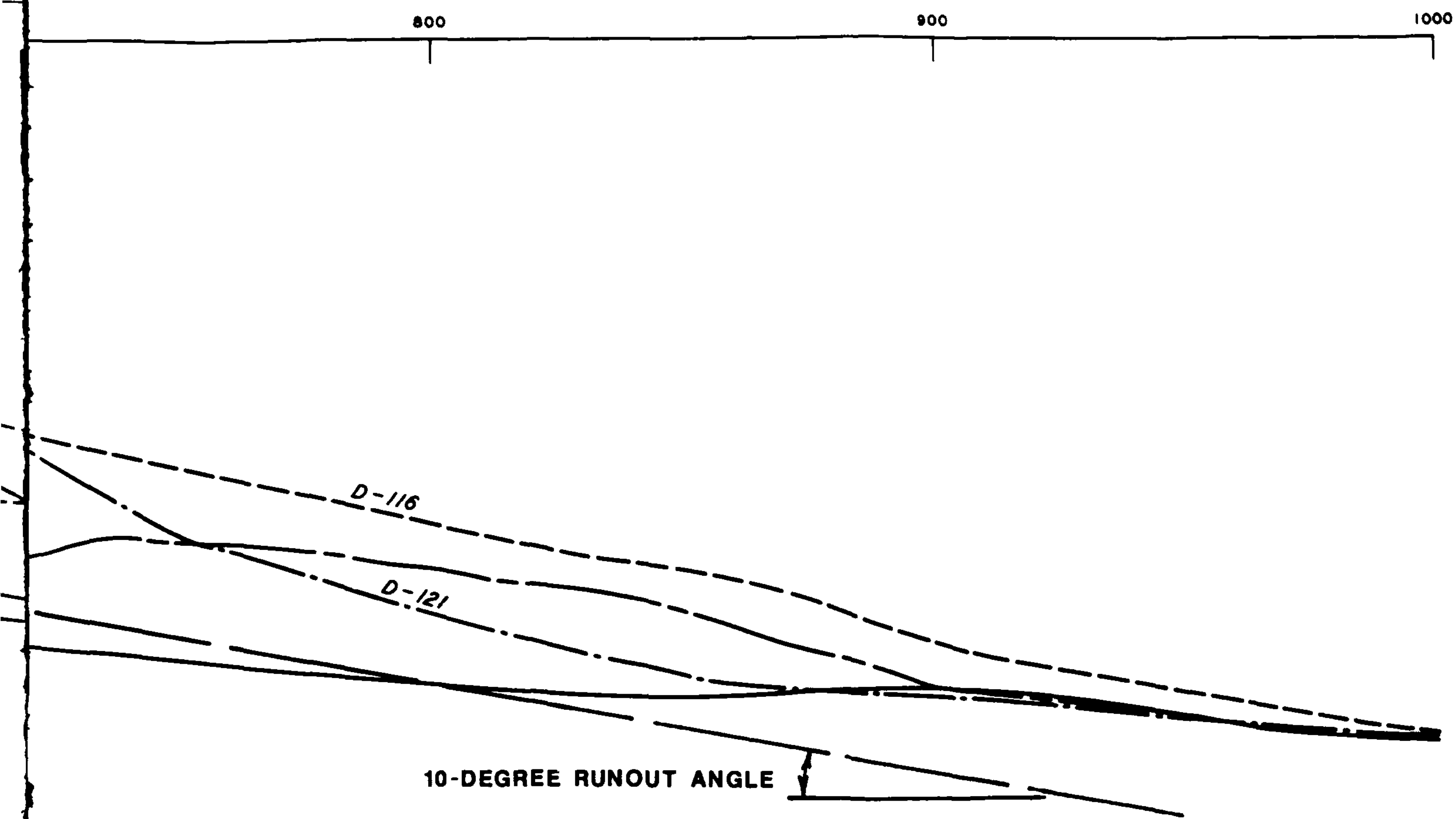
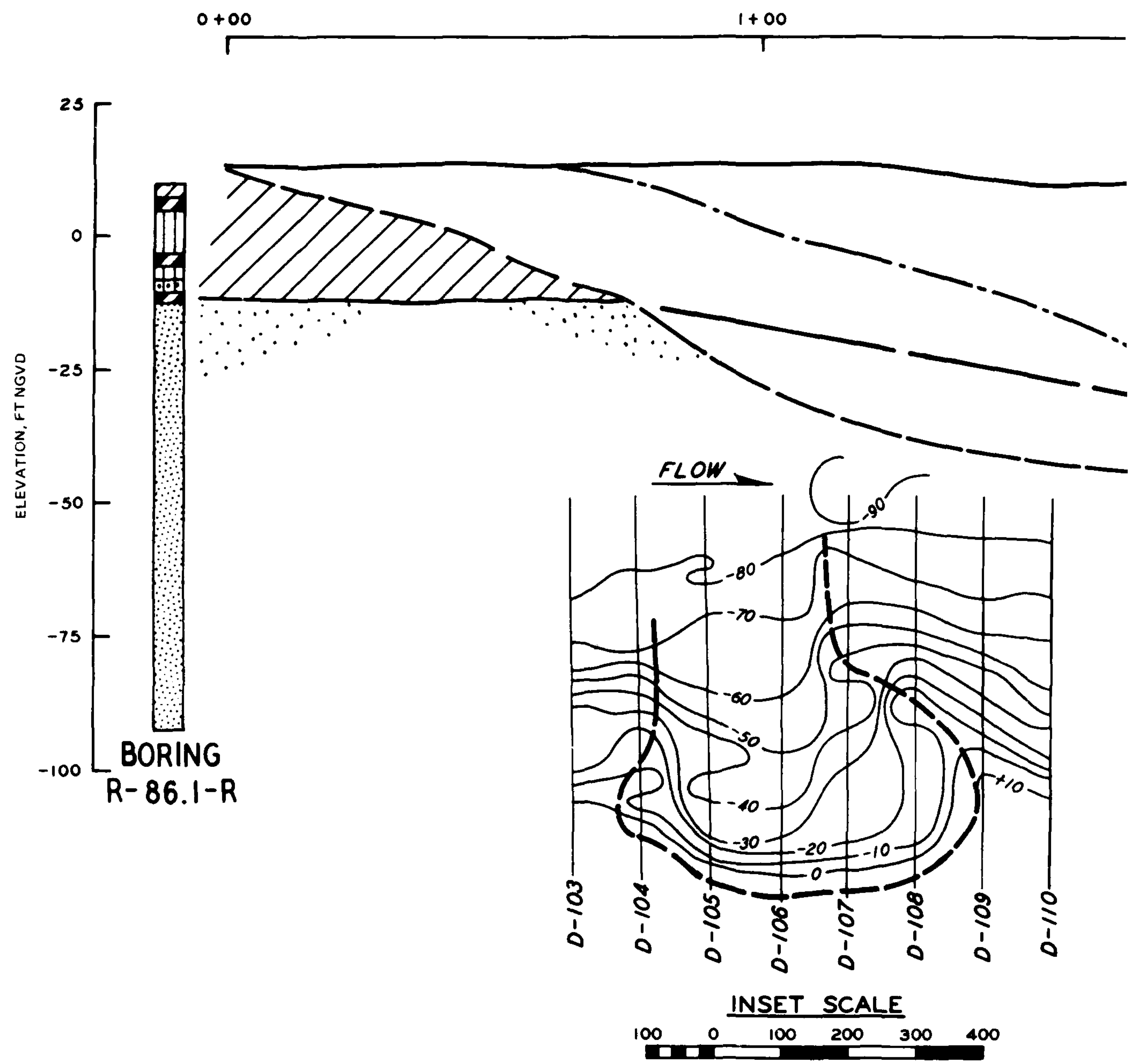
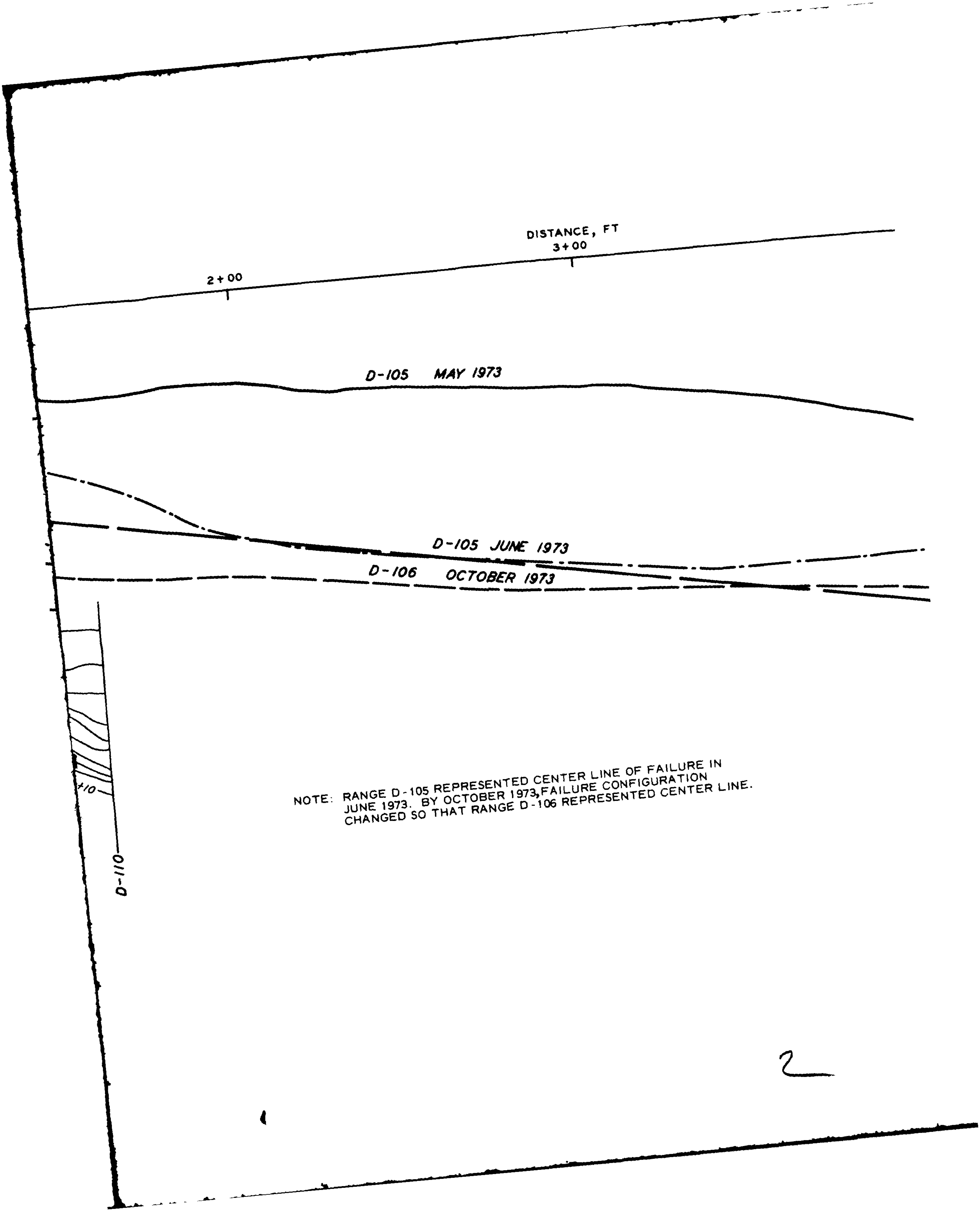


Figure 20. Sections perpendicular to the riverbank, 1973 failure at Montz, LA.

3


0+00
1+00
25
0
-25
-50
-75
-100
ELEVATION, FT NGVD
BORING
R-86.1-R
FLOW
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
+10
D-103
D-104
D-105
D-106
D-107
D-108
D-109
D-110
INSET SCALE
100
0
100
200
300
400


DISTANCE, FT
2+00
3+00
D-105 MAY 1973
D-105 JUNE 1973
D-106 OCTOBER 1973
+10
D-110
NOTE: RANGE D-105 REPRESENTED CENTER LINE OF FAILURE IN JUNE 1973. BY OCTOBER 1973, FAILURE CONFIGURATION CHANGED SO THAT RANGE D-106 REPRESENTED CENTER LINE.
2

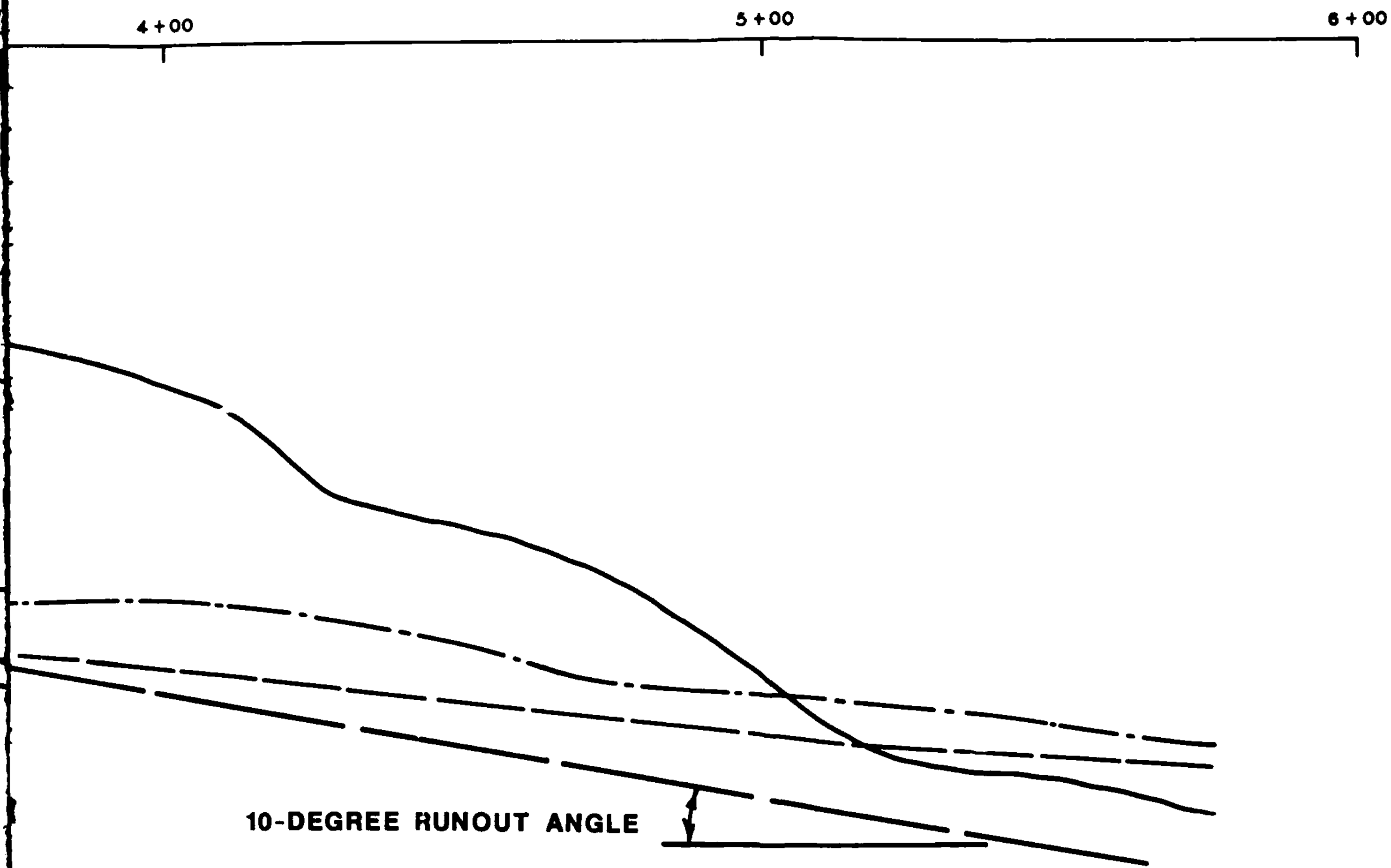
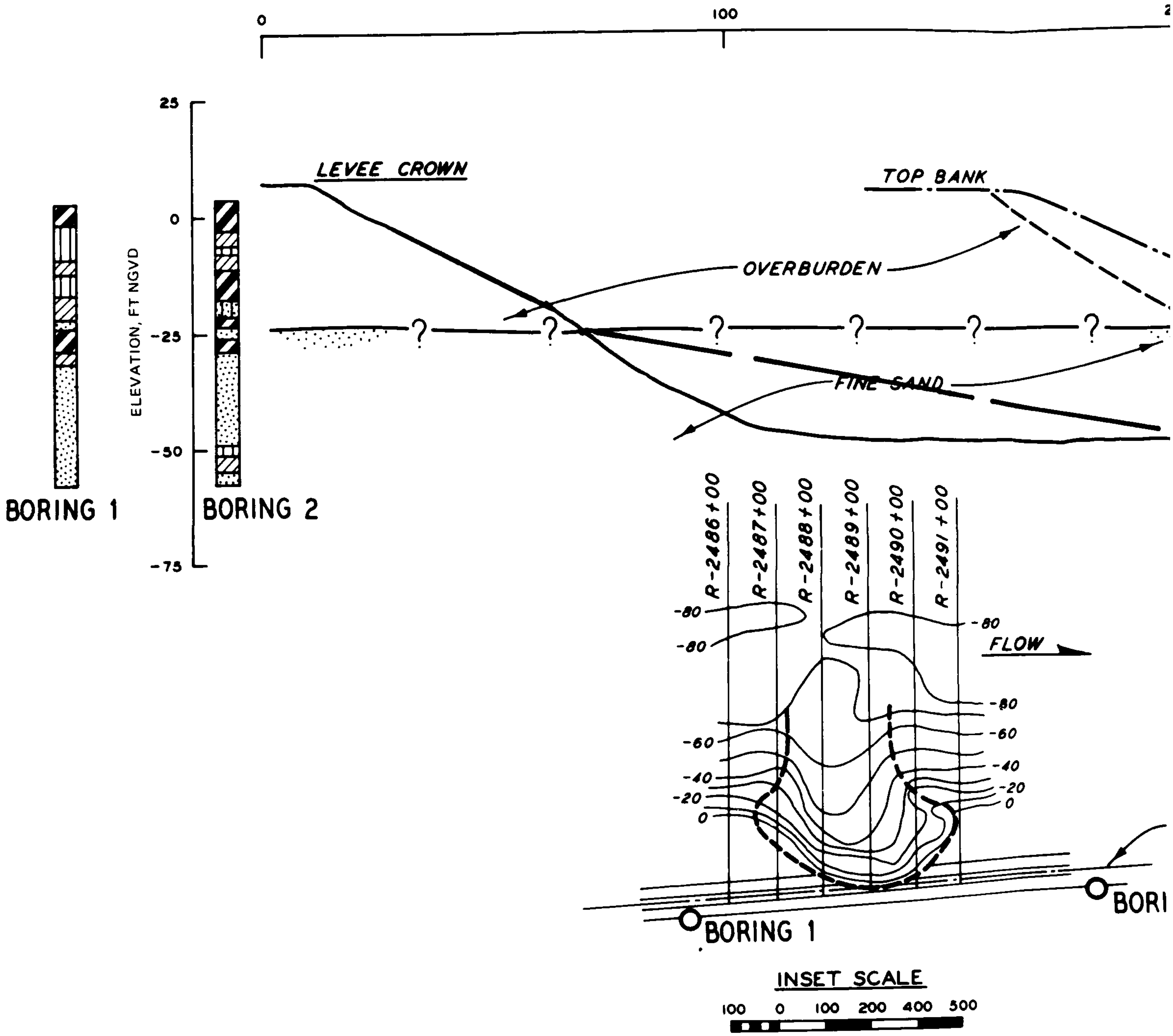


Figure 21. Sections perpendicular to the riverbank, 1973 failure at Stanton, LA.

3



0
100
25
0
-25
-50
-75
ELEVATION, FT NGVD
LEVEE CROWN
TOP BANK
OVERBURDEN
FINE SAND
BORING 1
BORING 2
R-2486+00
R-2487+00
R-2488+00
R-2489+00
R-2490+00
R-2491+00
-80
-60
-40
-20
0
FLOW
BORING 1
INSET SCALE
100 0 100 200 400 500

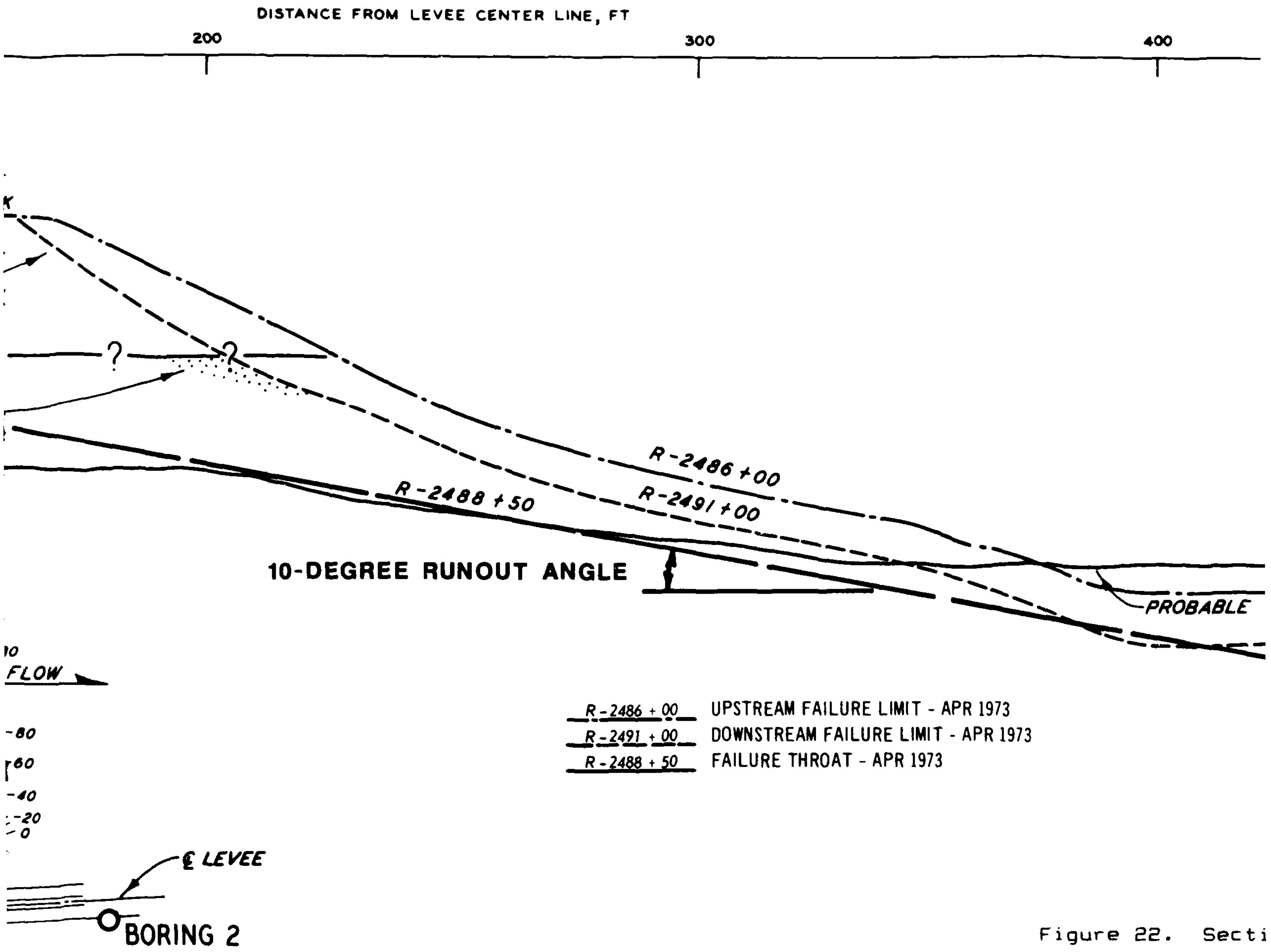


Figure 22. Secti

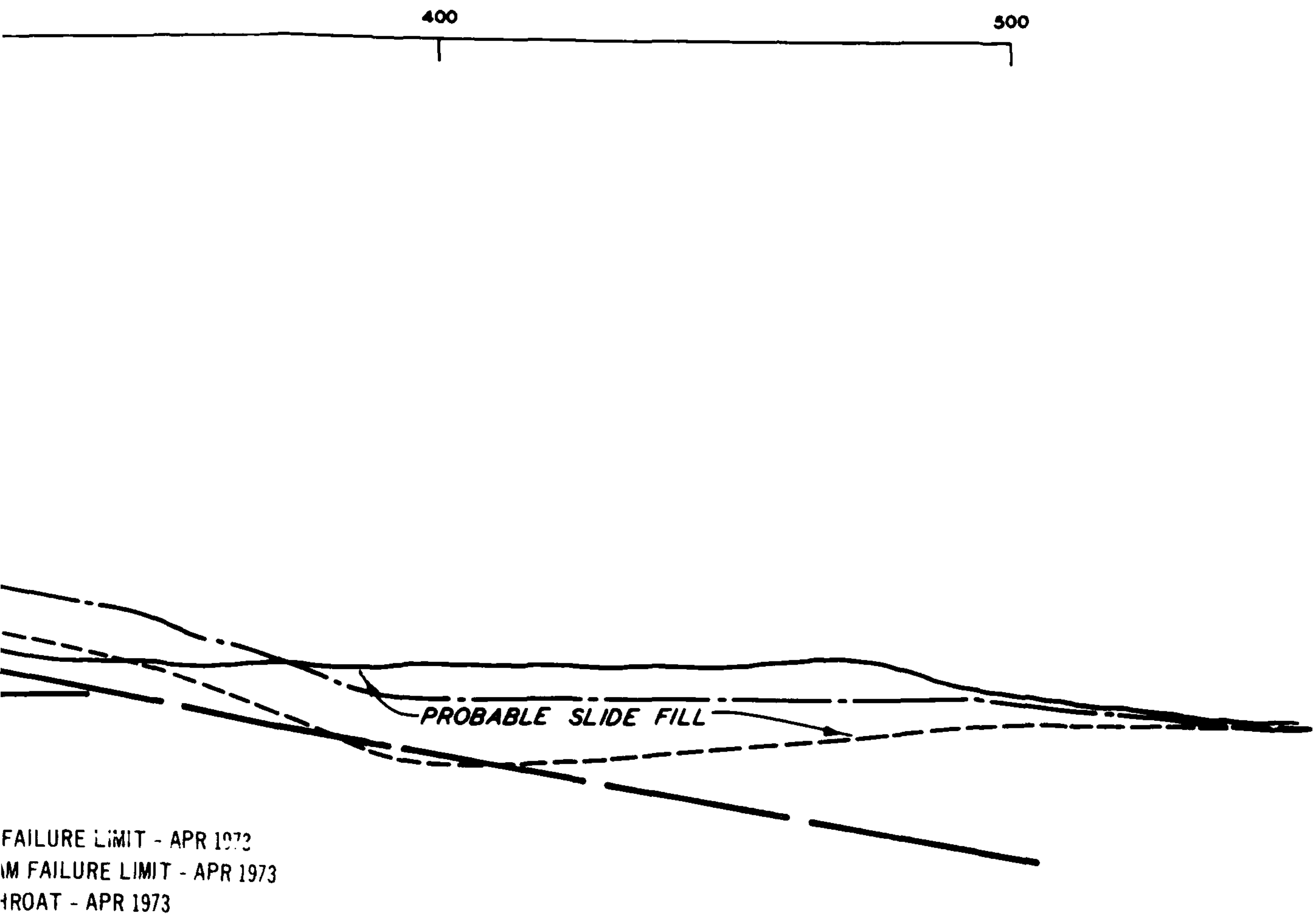


Figure 22. Sections perpendicular to the riverbank, 1973 failure at Nairn, LA.

approaching a minimally acceptable value, how close is too close? This question represents another unknown and another critical issue among many.

NOD Levee Safety Flow Slide Monitoring System

26. The NOD geotechnical staff has played a necessary and major role on many occasions through the years in the achievements of the flow slide studies. The monitoring system to be described below is their system. The author has served only in an advisory capacity. The following presentation of their system was provided by Mr. Jay Joseph, who was principally charged with and is credited for its development.

27. The flow failure susceptible areas below Baton Rouge have been assigned appropriate revetment ranges. The elevation of the top of the substratum sands has been identified from available soil borings in each area. Table 1 lists the susceptible bank reaches and their monitored limits.

28. Flow failure evaluation begins by examining available hydrographic survey data for scour which could trigger a failure. At the present time, this is accomplished by comparing current revetment maintenance surveys to revetment base surveys. Those areas experiencing scour are examined on a range-by-range basis to determine the extent of bank failure that would likely take place using the runout angle concept. The next step in the evaluation is to determine the effect the assumed bank failure would have on the adjacent levee. This is done by comparing the assumed failure with available levee stability control lines (SCL). An SCL is an imaginary boundary or envelope passing through the bank which is determined by conventional stability analyses as the maximum bank loss which can be suffered without the factor of safety falling below the minimum preferred value. At the present time, results of the flow failure evaluation by NOD at each revetment site are made available to the revetment planners to be used in prioritizing revetment work.

29. A computer program has been developed to facilitate the evaluation of the large number of revetment ranges shown in Table 1. The first part of the program extracts survey and SCL data currently stored in a data base on the US Army Engineer Waterways Experiment Station (WES) computer. This data file is transmitted to the NOD Harris computer. The second part of the program evaluates the data, identifying which areas are experiencing scour, which areas would likely result in a batture loss if flow occurs, and which of these

Table 1

Flow Failure Monitoring Limits

Revetment	Mile	River Ranges U/S	River Ranges D/S	Revetment Ranges U/S	Revetment Ranges D/S	Sand EL
Arlington	226.5 L	226.6	223.9	U-65	D-85	0
Manchac	215.5 L	219.0	217.5	U-250	U-150	-30
Plaquemine Bend	209.0 R	211.6	211.4	†	†	-20
Plaquemine Bend	209.0 R	204.5	203.0	D-205	D-280	0
Point Pleasant	201.3 R	201.2	200.3	U-24	D-20	0
White Castle	193.0 R	197.2	195.9	U-200	U-135	-10
White Castle	193.0 R	189.3	188.3	D-200	D-241	-10
New River Bend	185.0 L	191.3	191.02	U-300	U-280	-20
Philadelphia Point	182.5 R	182.9	181.7	U-5	D-50	-10
Smoke Bend	177.5 R	176.3	174.8	D-40	*D-138	-15
Aben	172.5 R	174.8	174.7	*U-132	U-90	-15
St. Alice	165.0 R	163.1	161.8	D-125	D-180	-60
Rich Bend	157.0 R	154.8	154.1	D-145	*D-177	-20
Rich Bend	157.0 R	154.1	153.1	*D-178	D-225	-35
Belmont	152.0 L	151.3	150.0	D-50	D-115	-30
Angelina	145.0 L	142.8	142.1	D-125	D-150	-15
Willow Bend	141.5 R	139.9	139.2	D-70	D-100	-35
Lucy	135.5 R	134.6	133.5	D-45	D-90	-7
Montz	132.5 L	130.4	128.9	D-115	D-175	-40
Waterford	128.5 R	125.8	125.2	D-120	D-150	-10
Goodhope	121.5 L	123.2	122.7	D-155	D-175	-60
Luling	119.0 R	115.0	113.5	D-152	D-240	-5
Kenner	113.7 L	109.7	109.2	D-210	D-230	-40
Carrollton	103.5 L	103.0	101.6	D-50	D-100	-16
Greenville	100.4 R	104.0	102.3	U-185	U-105	-30
Greenville	100.4 R	100.3	99.5	U-30	D-15	-11
Gretna Bend	96.7 R	96.5	96.4	D-10	*D-14	-30

(Continued)

* Flow failure limits overlap adjacent revetments.
** Last revetment range on layout - area extends beyond layout.
† No revetment layout available.

9 Dec 86

Table 1 (Concluded)

Revetment	Mile	River Ranges U/S	River Ranges D/S	Revetment Ranges U/S	Revetment Ranges D/S	Sand EL
Gouldsboro Bend	95.9 R	96.4	96.2	*U-15	U-5	-30
Algiers Point	95.0 R	94.9	94.6	D-10	D-20	-30
Third District Reach	92.9 L	89.3	88.1	D-135	D-157**	-30
Cutoff	88.5 R	93.4	91.3	U-260	U-155	-20
Cutoff	88.5 R	86.4	84.8	D-115	*D-184	-10
Twelve Mile Point	84.0 R	84.8	82.6	*U-67	R-0	-15
Poydras	82.0 L	82.8	82.3	U-30	D-5	-20
Scarsdale	75.0 L	77.3	76.6	U-120	U-85	-38
Scarsdale	75.0 L	73.9	72.9	D-60	D-115	-40
Oak Point	72.5 R	71.7	71.3	D-40	D-60	-40
Linwood	71.0 L	69.7	68.1	D-52	D-115	-35
Harlem	56.5 L	55.0	53.4	D-85	D-169	-25
Gravolet	51.0 L	49.1	48.8	D-70	D-90	-38
Junior	54.0 R	52.5	51.15	D-70	*D-141	-35
Diamond	48.5 R	51.15	50.9	*U-129	U-114	-15
Diamond	48.5 R	48.2	46.7	D-25	D-100	-30
Port Sulphur	39.0 R	35.2	32.6	D-210	D-254**	-20
Buras	25.1 R	23.4	23.25	D-80	*D-87	-20
Fort Jackson	21.5 R	23.25	23.0	*U-93	U-75	-20
Fort Jackson	21.5 R	20.4	20.0	D-47	D-65	-12
Olga	17.0 L	13.5	11.5	†	†	-20
Venice	12.5 R	12.5	11.5	D-105	D-160	-20

* Flow failure limits overlap adjacent revetments.
** Last revetment range on layout - area extends beyond layout.
† No revetment layout available.

9 Dec 86

areas would threaten the adjacent levee. A sample of the summary report generated by this program is shown as Table 2. The program also produces a graphics display on the computer terminal monitor of the cross section at any selected range. Figure 23 depicts that display. The pertinent SCL, the revetment base survey and current Fathometer surveys, and the assumed flow failure runout angle (retrogressive control line, RCL) projected at 10 deg from the scour pool are shown in Figure 23, and appropriate legends are printed below the plot. The plots can be altered in scale as desired, and hard copies can be produced at the office terminal or on the Calcomp plotter in colors. The runout angle is an input variable so that should an angle other than 10 deg ever be considered more appropriate, basic programming changes will not be required.

30. Many locations have been examined for flow failure potential using 1985 and 1986 revetment surveys. Results of those evaluations have already been included in revetment planning. However, the job of monitoring potential flow failure areas has just begun. Many areas listed in Table 1 lack the hydrographic surveys required to permit evaluation. Surveys of these reaches will be accomplished on a priority basis over the next several years. With time, the frequency of the surveys in some areas will likely be reduced if no evidence of scour is seen. Areas will have to be added to or deleted from the list as more data become available. Furthermore, refinements and improvements in the computer programs are already under way to provide the user with additional comparative plots of changes indicated by hydrographic surveys and greater flexibility in drawing information from the data base.

31. The author points out that the long list of sites to be monitored is the result of an initial philosophy that no reaches exhibiting thin top stratum over sands will be omitted. Under this approach, the future will see deletion of some reaches but only on the basis of the sufficient data justifying deletion.

Table 2

Flow Slide Summary Report

```
                                                          15 JAN 87    PAGE    1

RANGES NOTED INDICATE 7 FEET OR MORE SCOUR FROM BASE SURVEY ELEVATION.
•  REGRESSION CONTROL LINE (RCL) INTERSECTS SAND CLAY INTERFACE.
$  REGRESSION CONTROL LINE INTERSECTS STABILITY CONTROL LINE.
#  SOME RANGES SUSCEPTIBLE TO FLOW SLIDE WERE NOT INCLUDED IN INPUT FILE.
?  STABILITY CONTROL LINE FOR RANGE NOT INCLUDED IN INPUT FILE.
THE REGRESSION CONTROL LINE ANGLE IS   10.0  DEGREES.

PROGRAM  6013VW•FLOSLIDE     INPUT FILE 13S0A0•I574017C

                           SURVEY
LOCATION              MILE YEAR    RANGES HAVING SCOUR HOLES 7 FOOT OR MORE

ALGIERS POINT          95R 1986 •D-014 $D-015 •D-016?•D-017?•D-018?•D-019?•D-020?
ANGELINA#             145L 1986 •D-125  D-126 •D-127  D-128 •D-129 •D-130 •D-131
                                •D-132 •D-133 •D-134 •D-135 •D-137 •D-138 •D-139
                                •D-140 •D-141 •D-143 •D-144
ARLINGTON#            226L 1986 •U-028 •U-023 •U-021 •U-011 •U-003 •D-002 •D-005
                                •D-006 •D-009 •D-035 •D-040 •D-041 •D-042 •D-043
                                •D-044 •D-046 •D-048 •D-049 •D-050 •D-051 •D-058
                                •D-060 •D-062 •D-064 •D-065 •D-066 •D-067 •D-068
                                •D-074  D-080  D-081 •D-083
BELMONT               152L 1986.•D-050 •D-051 •D-052 •D-053 •D-054 •D-055 •D-056
                                •D-057 •D-058 •D-059 •D-060 •D-061 •D-062 •D-063
                                •D-064 •D-065 •D-067  D-070  D-072 •D-073 •D-074
                                 D-075 •D-076  D-077  D-078  D-079  D-080  D-082
                                •D-083 •D-084 •D-085 •D-086 •D-087 •D-088 •D-089
                                •D-099 •D-101 •D-102 •D-103  D-104 •D-106 •D-108
                                •D-111 $D-112  D-113  D-114
CARROLLTON            104L 1986 •D-058?•D-061?•D-062?•D-065? D-066?•D-069?•D-072?
                                •D-073? D-076?•D-077?•D-078?•D-079?•D-080?•D-081?
                                •D-082?•D-083?•D-084?•D-085?•D-087?•D-088?•D-089?
                                •D-090?•D-091?•D-092?•D-093?•D-094?•D-095?•D-097?
                                •D-098?•D-099?•D-100?
CUTOFF -2#             88R 1986 •D-115  D-116 $D-118 $D-119 •D-126 •D-128  D-131
                                •D-136 •D-137  D-138  D-139  D-140  D-141  D-142
                                 D-143 $D-144 •D-146
DIAMOND -2#            48R 1986 •D-025 •D-026 •D-027 •D-028 •D-029 •D-030 •D-031
                                •D-032 •D-033 •D-034 •D-035  D-036 •D-037 •D-038
                                •D-039  D-040  D-041  D-042  D-043  D-044  D-045
                                •D-046  D-047  D-048  D-049  D-050  D-051 •D-052
FORT JACKSON -2        22R 1986 •D-047?•D-048?•D-049?•D-050?•D-051?•D-052?•D-053?
                                •D-054?•D-055?•D-056?•D-057?•D-058?•D-059?•D-060?
                                •D-061?•D-062?•D-063?•D-064?•D-065?
GOODHOPE#             122L 1986 •D-175
GOULDSBORO BEND        96R 1986 •U-014?•U-013?•U-010?•U-008?•U-007?•U-006?•U-005?
GRAVOLET#              51L 1986  D-071  D-073  D-074  D-075  D-076  D-077  D-078
                                 D-079 •D-080 •D-081 •D-083
GREENVILLE -2         100R 1986 •U-030 •U-029 •U-028 •U-027 •U-026 •U-025 •U-024
                                •U-023 •U-022  U-020 $U-019 •U-016 •U-015 •U-014
                                •U-011 •U-010 •U-009 •U-008 •U-007 •U-006 •U-005
                                •U-003 •U-002 •U-001 •D-001  D-002  D-003 •D-004
                                 D-005  D-006 •D-011 $D-014
GRETNA BEND            97R 1986 •D-010?•D-011?•D-012? D-013?•D-014?
JUNIOR#                54R 1986 •D-070 •D-071 •D-072 •D-073 •D-074 •D-075 •D-076
                                •D-077 •D-078 •D-079 $D-080 $D-081 $D-082 $D-083
                                $D-084 $D-085 $D-086 $D-087 $D-088  D-089 $D-090
                                $D-091 $D-092  D-093 •D-094
KENNER#               114L 1986 •D-213  D-227  D-228
```

(Continued)

(Sheet 1 of 3)

Table 2 (Continued)

15 JAN 87 PAGE 2

RANGES NOTED INDICATE 7 FEET OR MORE SCOUR FROM BASE SURVEY ELEVATION.
• REGRESSION CONTROL LINE (RCL) INTERSECTS SAND CLAY INTERFACE.
$ REGRESSION CONTROL LINE INTERSECTS STABILITY CONTROL LINE.
# SOME RANGES SUSCEPTIBLE TO FLOW SLIDE WERE NOT INCLUDED IN INPUT FILE.
? STABILITY CONTROL LINE FOR RANGE NOT INCLUDED IN INPUT FILE.
THE REGRESSION CONTROL LINE ANGLE IS 10.0 DEGREES.

PROGRAM 6013VW•FLOSLIDE INPUT FILE 13S0A0•I574017C

LOCATION	MILE	SURVEY YEAR	RANGES HAVING SCOUR HOLES 7 FOOT OR MORE
LINWOOD#	71L	1986	NONE
LUCY#	136R	1986	D-045 •D-077 D-082
LULING#	119R	1986	•D-153 D-163 •D-172 D-173 •D-177 D-178 D-183
			•D-187
MANCHAC#	215L	1986	U-175 U-170 •U-166 •U-165 U-155 •U-154
MONTZ#	132L	1986	D-115 D-119 •D-120 D-121 •D-126 •D-137?•D-138?
NEW RIVER BEND	185L	1986	•U-300 •U-299 U-298 U-297 U-296 $U-295 $U-294
			$U-293 U-292 $U-291 U-290 $U-289 U-288 U-287
			U-286 U-285 U-284 •U-283 U-282 •U-281 U-280
OAK POINT	72R	1986	•D-040 •D-041 •D-042 •D-043 •D-044 •D-045 •D-046
			D-047 D-048 •D-049 D-050 •D-051 •D-052 D-054
			D-055 D-056 •D-057 D-058 •D-059 •D-060
PHILADELPHIA PT.	182R	1986	•U-002 •U-001 •D-017 •D-025 •D-026 •D-041 •D-042
			•D-047 •D-049 D-050
PLAQUEMINE BEND#	209R	1986	•D-207 •D-212 •D-213 •D-214 •D-216 •D-217 •D-218
			•D-219 •D-222 •D-223 •D-224 •D-227 •D-229 D-231
			D-236
PORT SULPHUR#	39R	1986	•D-210 •D-211 •D-212 •D-213 •D-214 •D-215 $D-216
			$D-217 $D-218 $D-219 $D-220 $D-221 $D-222 $D-223
			$D-224 $D-225 $D-226 $D-227 $D-228 $D-229 $D-230
			$D-231 $D-232 $D-233 $D-234 $D-235 $D-236 $D-237
			$D-238 •D-242 •D-246 •D-247 •D-248 •D-249 •D-250
			•D-251 •D-252
POYDRAS	82L	1986	•U-019 •U-017 •U-016 •U-015 •U-014 •U-013 •U-011
			•U-010 •U-008 •U-004 •U-002 •D-001 •D-002 •D-003
			•D-004
RICH BEND -1#	157R	1986	•D-166 D-171 $D-175
RICH BEND -2	157R	1986	D-208
SCARSDALE -1#	75L	1986	NONE
SCARSDALE -2#	75L	1986	•D-060 •D-061 •D-062 •D-063 •D-064 •D-065 •D-066
			$D-067 •D-068 •D-069 •D-070 •D-071 •D-072 •D-073
			•D-074 •D-075 •D-076 •D-077 •D-078 •D-079 •D-080
			•D-081 •D-082 D-083 •D-084 D-085 D-086 D-087
			D-088 D-089 D-090 D-091 D-092 D-093 D-094
			•D-095 •D-096 •D-097 •D-098 •D-099 •D-100 •D-102
SMOKE BEND#	178R	1986	•D-040 •D-041 D-042 D-043 D-044 D-045 D-046
			D-047 D-048 D-049 D-050 •D-051 D-052 •D-053
			•D-054 •D-055 •D-056 •D-057 •D-058 •D-059 •D-060
			•D-061 D-062 D-063 •D-065 •D-072 •D-077 •D-081
			•D-083 •D-085 •D-088 •D-089 •D-090 •D-091 •D-098
			•D-103 •D-106 •D-109 •D-110 •D-111
ST. ALICE#	165R	1986	D-126 •D-127 •D-128 •D-129 •D-130 •D-131 •D-132
			•D-133 •D-134 •D-135 •D-136 •D-137 •D-139 •D-140
			•D-141 •D-142 •D-143 •D-144 •D-146 •D-147 •D-148
			•D-149 •D-154 •D-155 •D-156 •D-157 •D-158 •D-159

(Continued)

(Sheet 2 of 3)

Table 2 (Concluded)

15 JAN 87 PAGE 3

RANGES NOTED INDICATE 7 FEET OR MORE SCOUR FROM BASE SURVEY ELEVATION.
• REGRESSION CONTROL LINE (RCL) INTERSECTS SAND CLAY INTERFACE.
$ REGRESSION CONTROL LINE INTERSECTS STABILITY CONTROL LINE.
# SOME RANGES SUSCEPTIBLE TO FLOW SLIDE WERE NOT INCLUDED IN INPUT FILE.
? STABILITY CONTROL LINE FOR RANGE NOT INCLUDED IN INPUT FILE.
THE REGRESSION CONTROL LINE ANGLE IS 10.0 DEGREES.

PROGRAM U013VW.FLOSLIDE INPUT FILE 13S0A0.I574017C

LOCATION	MILE	SURVEY YEAR	RANGES HAVING SCOUR HOLES 7 FOOT OR MORE
ST. ALICE#	165R	1986	•D-161 •D-162 •D-164 •D-166 •D-167 •D-168 •D-169 •D-170 •D-172 •D-174 •D-175 •D-176?
THIRD DIST. REACH#	93L	1986	NONE
VENICE	12R	1986	•D-108 •D-109 •D-122 •D-123 •D-137 D-143 D-144 $D-145 D-156 •D-157
WATERFORD#	128R	1986	•D-120 •D-121 •D-122 •D-123 •D-124 •D-125 •D-126 •D-127 •D-128 •D-129 •D-130 •D-131 •D-132 •D-133 •D-134
WHITE CASTLE -1	193R	1986	•U-183 •U-166 •U-162 •U-158 •U-157 •U-156 •U-155 •U-154 •U-153 •U-152 •U-151 •U-150 •U-149 •U-139 •U-138
WILLOW BEND#	142R	1986	•D-070 •D-071 •D-072 D-073 D-074 •D-075 •D-077 •D-078 •D-079 •D-082 •D-084 •D-085 •D-086 D-088 D-089 D-090 D-091 D-092 D-093

(Sheet 3 of 3)

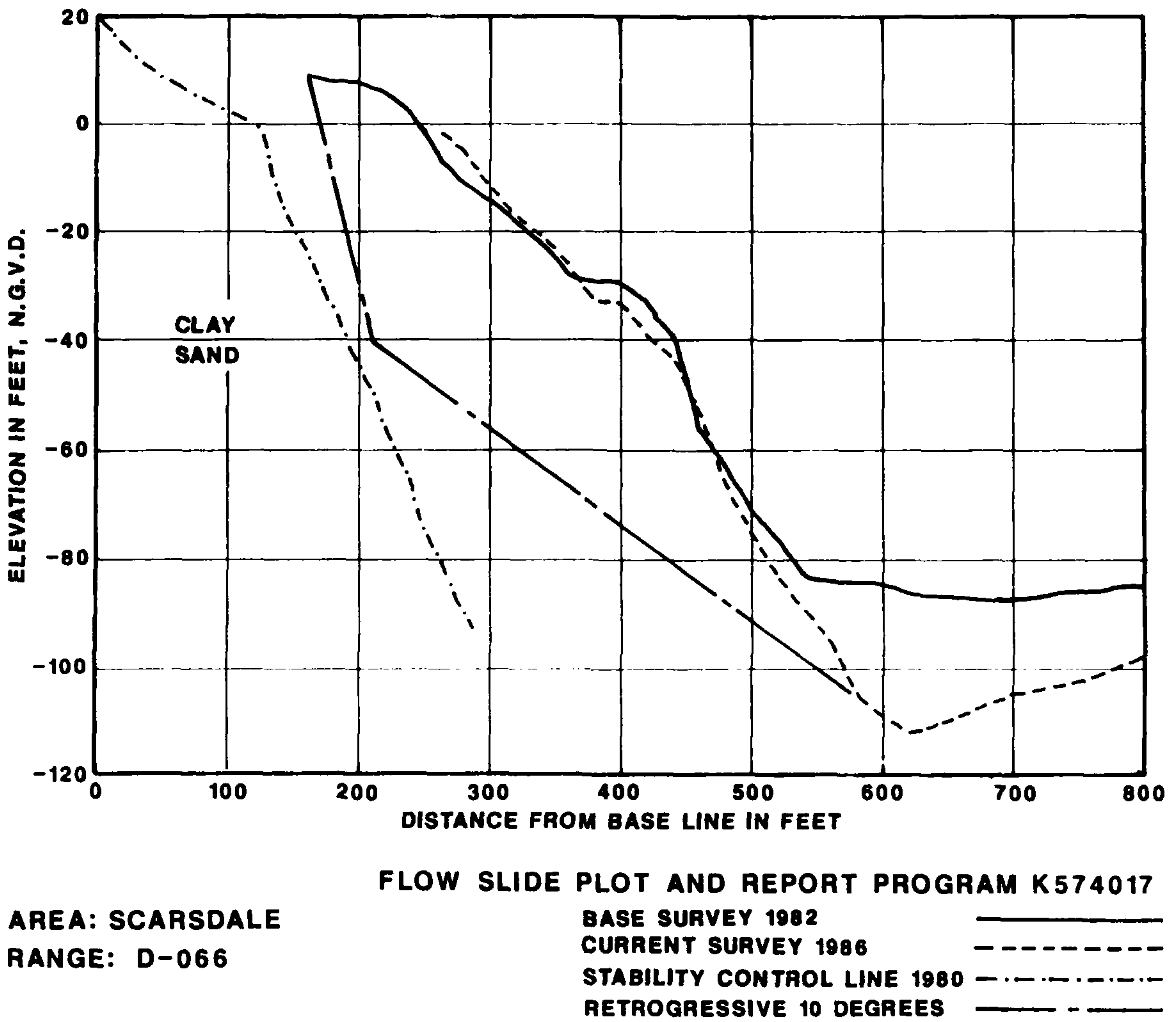


Figure 23. Example of computer graphics output, Levee Safety Flow Slide Monitoring System

PART IV: HISTORICAL RIVER MOVEMENT AND ITS IMPLICATIONS

Background

32. Since WES geologists have been conducting specific flow failure site studies employing old hydrographic surveys of the river below Baton Rouge, the data were available to compare the oldest available surveys (1879-1894) with the latest (1973-1975). The comparative bank lines between the two survey data sets are given in Appendix A. The bank lines roughly correspond to the Low Water Reference Plane (LWRP).

33. Also significant to the discussion to follow is the complete compilation of pertinent soil boring data contained within NOD files for the entire reach of river below Baton Rouge, LA. Appendix B consists of that boring data for both right and left descending banks from Wilkinson Point at mile 235 AHP (Baton Rouge) to the lower end of the mainline levee system on the left descending bank at mile 10 AHP. Borings considered too distant from the top of the bank to be pertinent to bank/levee stability problems are not included. The boring logs of Appendix B are intended to show the presence of significant substrata of sand. Blank segments on the individual logs represent clays, silts, or insignificant strata (less than 5 ft) of sands. The compilation has proven to be very useful in establishing the overburden/sand interface on a site-by-site basis for use in the monitoring program previously described.

Implications of the Historical Data

34. Based on bank line changes observed by comparing the oldest hydrographic surveys with the latest surveys, a pattern emerges telling the expectable story of the river's continuing attempts to change its alignment in directions typical of meandering. All of the reaches exhibiting the larger historical bank losses also exhibit the presence of the least erosion-resistant soils, i.e., sands and/or silty sands. Whether the sands are exposed to river attack near surface or beneath considerable thicknesses of clayey top strata, the river's attack has been very successful along many reaches and should be expected to continue. Where the sands are near surface (50 ft or less), the largest bank losses of record have been measured in magnitudes of thousands of feet. What bank revetment has done to mitigate these

losses has not been fully established because the revetment program below Baton Rouge is not old in terms of cycles of river attack. The loss of revetted bank is a commonality within the LMVD testified to by the size of the annual maintenance program. The author suspects that past maintenance requirements on a site-by-site basis could be strongly correlated to the presence of significant sand strata in the bank.

35. Within the context of the chronic attack described above is that of the relatively rare severe flood periods. As were previously identified (by letter to LMVD in 1979), there are numerous reaches in point bar deposits on the upstream inside of bendways which are obviously subjected to especially severe erosion during such high stages. Where significant strata of fine sands and/or silty sands are present under thin top strata, major flow slides are likely. Major failure scars mark these locations with regularity below Baton Rouge and upriver as well. Within these reaches of persistent historical erosion, old bank line surveys regularly show the presence of large scallops (suggesting flow slides) chronologically marching landward at about the same location. Extreme flood periods seem to be the key to these failures (except Celotex) because they have not been observed during "normal" annual high water periods. Flow slides during extreme events are most dangerous because they may occur during times when water is over the batture and against the levees and may consequently be invisible. During normal high water these reaches may experience bank losses by general erosion which does not trigger flow slides or at least not ones that have been noted.

36. With the studies associated with the Marchand batture and levee failure (left descending bank, mile 180.7 AHP) of 23 August 1983 came yet another dimension to the problem of the role of sands in bank stability. At this site, overburden deposits average 120 ft in thickness and were underlaid by sands and silty sands below el -96. The thalweg of the river was at el -150 and in a scour trench in the sands at the toe of the river bank. The final internal report prepared by the NOD in October 1984 stated as follows:

> A review of surveys made at the failure location since 1971 indicates that an initial deep-seated slide occurred in the underwater bank in 1973 as a result of toe scour in the sand at the base of the slope. This initial slide weakened the underwater bank and led to successive failure of the upper slope. This progression led to eventual loss of the upper bank, reducing significantly the passive resistance to levee failure.

> The 1983 bank failure was the last in a sequence of failures resulting from continuous bank scour.

There is no reason to discount the possibility of runout of sands in the retrogressive manner as the initial failure referred to above. The process of failure in a thick, cohesive overburden stratum undercut by loss of underlying sand has not been addressed. It is an unusual geotechnical problem meriting study.

37. Turning to the historical river movement data and soils data of Appendices A and B, respectively, a pattern can be seen. It is obvious that the river has commonly and successfully eroded banks exhibiting soil profiles similar to that at Marchand, i.e., thick overburden over deep sands. The author is of the opinion that the failure sequence described for Marchand is a usual one.

38. It was decided to quantify the river's movement by scaling the erosion or deposition in feet of batture from the sheets of Appendix A at every other one of the 1,328 hydrographic ranges from range R-234.8 (Baton Rouge) to range R-10.6 (lower end of mainline levees). The 661 discrete data obtained in this manner are given in Appendix C for both right and left banks. These data were used to categorize the severity of historical bank losses by reach. The categories are the arbitrary choice of th author and are as follows:

- a. Severe losses - 1,000 or more feet of bank recession over the 90-year period of record. These reaches are listed in Table 3 with comments verifying the regularity of thalweg in deep sands.
- b. Modera e losses - 500 to 999 ft of bank recession over the period of record. These reaches are listed in Table 4 with comments.
- c. Minor losses - less than 500 ft of bank recession over the period of record. These reaches are listed in Table 5 with no comment.

All of the four major flow failures during the flood of 1973 occurred within reaches listed as suffering severe to moderate bank losses over the period of record. It is interesting to note that the Greenville Bend reach including the Celotex failure site has suffered only about 450 ft, i.e., minor bank recession over the period of record.

39. It is emphasized that the data given in Tables 3-5 are intended to serve as a form of attack classification as opposed to a flow slide susceptibility classification. Put simply, it is reasonable to believe that any

Table 3

Chronic Problem Reaches, Severe Bank Losses of 1,000 ft or More

Total Reach Range to Range	Subreach of Maximum Loss Range To Range	Maximum Bank Loss ft	Comments
		Right Bank	
221.9 to 218.8	221.2 to 219.1	2,550 ft at R-220.0-R	Sand below el -100 Thalweg in the sand
211.3 to 209.6	210.8 to 209.0	1,050 ft at R-210.1-R	Sands at variable depth below el -50 Thalweg in the sand
206.4 to 204.0	205.5 to 204.3	1,690 ft at R-204.8-R (1973 Plaquemine failures)	Sands below el 0 from R-204.7 to R204.0 Thalweg in the sand in this reach
197.9 to 191.6	195.9 to 194.0	1,300 ft at R-194.7-R	Sand below el -90 Thalweg in the sand
173.0 to 171.9	172.8 to 172.1	1,000 ft at R-172.5-R	Sand below el -110 Thalweg in the sand
157.4 to 152.9	156.4 to 155.7	1,300 ft at R-156.1-R	Sand below el -70 Thalweg in the sand
136.8 to 133.8	135.0 to 133.8	1,050 ft at R-134.6-R and R-134.2-R	Sand below el -20 Thalweg in the sand
89.6 to 85.9	88.1 to 86.2	1,000 ft at R-87.4-R (1973 Stanton failure)	Sand at variable depths from el -10 to el -70; thalweg in the sand
69.5 to 65.9	68.9 to 67.8	1,000 ft at R-68.5-R	Sand from el -100 to -120 Thalweg in the sand
44.8 to 43.4	44.8 to 43.4	1,125 ft at R-44.1-R	Sand below el -40 Thalweg in the sand

(Continued)

Table 3 (Concluded)

Total Reach Range to Range	Subreach of Maximum Loss Range To Range	Maximum Bank Loss ft	Comments
		Left Bank	
227.2 to 224.4	225.9 to 224.7	1,750 ft at R-225.6-L	Sand below el -60 Thalweg in the sand
218.5 to 216.8	217.8 to 217.1	1,200 ft at R-217.8-L	Sand below el -50 Thalweg in the sand
214.9 to 212.2	214.6 to 213.6	1,150 ft at R-214.3-L	Sand below el -80 Thalweg in the sand
200.3 to 198.1	199.9 to 199.0	1,300 ft at R-199.3-L	Sand below el -100 Thalweg in the sand
188.8 to 183.2	187.9 to 184.6	1,500 ft from R-187.0 to R-186.4-L	Sand at variable depths from el -60 to -80; thalweg in the sand
181.1 to 178.5	181.0 to 178.8	1,900 ft at R-176.6-L (1983 Marchand Levee failure)	Sand at variable depths from el -30 to -100; thalweg at el -80
152.9 to 150.1	152.3 to 150.1	1,700 ft at R-150.7-L	Sands at variable depths from el -10 to -80; thalweg in the sand
144.5 to 142.6	144.5 to 142.6	1,750 ft at R-143.0-L	Sand at variable depths from el -50 to el -130; thalweg el -80 to -100
133.0 to 130.2	132.5 to 130.6	2,400 ft at R-130.9-L (1973 Montz failure)	Sand downstream of R-130.9 at variable depths from el -20 to -80; thalweg at el -60 to -120
34.6 to 31.6	33.8 to 33.0	1,750 ft at R-33.4-L	Sand below el -30 Thalweg in the sand

Table 4

Chronic Problem Reaches, Moderate Bank Losses of 500 to 999 ft

Total Reach Range to Range	Maximum Bank Loss ft	Comments
		Right Bank
178.1 to 175.9	525 ft at R-177.1-R	Sand at variable depths from below el -30 to -100; shallow sands at lower end; thalweg in the sand
166.3 to 162.4	775 ft at R-164.6-R	Sand at variable depths from el -40 to -150 Thalweg in the sand from R-164.6 to R-162.4
141.6 to 140.4	700 ft at R-141.6-R	Sand at variable depths from el -60 to -100 Thalweg at el -70 to -100
39.6 to 34.2	825 ft at R-35.2-R (1973 Nairn failure)	Sand at variable depths from el -20 to -50 Thalweg in the sand
22.1 to 19.6	900 ft at R-21.6-R	Sand only at R-20.2 Thalweg in the sand at that range
		Left Bank
175.4 to 173.3	550 ft at R-173.7-L	Sand below el -40 Thalweg in the sand
125.6 to 123.2	500 ft at R-123.7-L	Sand below el -180 at R-123.7; other borings not deep enough to determine if sand below thalweg; thalweg at el -160
115.6 to 109.7	600 ft at R-110.95-L	Sand below el -70 Thalweg on opposite bank
81.7 to 80.1	850 ft at R-81.1-L	Sand at variable depths from el -60 to -80; thalweg at el -50 to -60; very shallow sands from R-82.8 to R-82.5; if river deepens, could lose levee here

(Continued)

Table 4 (Concluded)

Total Reach Range to Range	Maximum Bank Loss ft	Comments
		Left Bank (Continued)
75.8 to 73.2	600 ft at R-74.2-L	Sand at variable depths below el -70; thalweg in the sand; shallow sand from R-73.5 to R-72.9; if river deepens at R-73.4, could lose levee
61.4 to 60.1	500 ft at R-60.4-L	No sand above el -130; thalweg not in sand
51.7 to 49.0	500 ft at R-50.3 to R-49.7-L	No sand above el -100 from R-51.6 to R-49.5 and thalweg not in sand; sand below el -50 at R-49.0; thalweg in the sand

Table 5

Chronic Problem Reaches, Minor Bank Losses of Less Than 500 ft

Reach Range to Range	Maximum Bank Loss of Record
Right Bank	
229.6 to 227.8	450
209.6 to 205.8	400
182.6 to 181.7	300
169.6 to 169.0	200
149.8 to 148.4	250
129.4 to 127.7	325
122.7 to 120.3	450
119.5 to 115.6	350
108.7 to 105.2	450
101.8 to 98.4	450 (1985 Celotex failure)
96.6 to 95.8	200
84.1 to 82.6	350
79.7 to 79.0	200
78.1 to 75.5	375
73.5 to 71.9	475
63.9 to 61.8	250
59.8 to 52.1	400
49.7 to 48.2	250
31.6 to 25.2	450
13.2 to 11.8	200
Left Bank	
202.8 to 202.2	400
197.0 to 196.4	200
162.1 to 160.3	350
138.1 to 136.4	400
103.8 to 102.5	200
85.7 to 83.4	350
79.4 to 78.1	350
71.5 to 70.2	375
65.9 to 62.9	400
57.3 to 55.3	250
41.6 to 39.3	225
38.3 to 37.6	200
28.6 to 26.9	200

reaches classified as susceptible to flow failure which also appear in Tables 3-5 are at very high risk. In addition, those reaches appearing in Tables 3 and 4, i.e., under severe to moderate attack where thick overburden overlies sand and the thalweg is in the sand against the bank in question, should also be considered at high risk.

Selected Statistical Summaries of Historical Changes

40. The discrete data of historical erosion and deposition given in Appendix C are plotted for the right and left banks in Figures 24 and 25, respectively. It is striking to see for both banks that the magnitudes of the river's movements and the frequency of those magnitudes are distinctly larger above (upriver) hydrographic range R-130 at the Bonnet Carre Spillway than below (downriver). The NOD geologist, Mr. Fred Smith, attributes this to a change in the geologic setting wherein more erosion-resistant Prodelta clays begin to occur regularly in the soil profile of the banks. Figure 26 presents the same data plotted as right bank versus left bank. If a line with a unit negative slope, -1, is also plotted in Figure 26 as shown, it divides the data into the set of ranges where a net narrowing of the channel occurred (points above the line) and where a net widening occurred (points below the line). In Report 1 (Torrey, Dunbar, and Peterson 1988), Dunbar calculated the total batture area of historic deposition and the total batture area of historic erosion for a 10-mile reach of river including the Bonnet Carre Point and Montz flow slide sites. He found only a 7-acre difference between erosion and deposition through the two bendways examined. The processes of erosion and deposition appear to be approximately balanced below Baton Rouge. Figures 27 and 28 break the total data set into that above hydrographic range R-129.8 (Bonnet Carre Spillway) and that below. These two figures really bring out the very different range of variations between the two subreaches and reveal the predominance of net channel narrowing between ranges 234.8 to 129.8 and predominance of net channel widening below range 129.8. Figures 29-34 present the erosion/deposition data in the form of frequency histograms. The histograms reveal the following:

a. For the entire reach of river below Baton Rouge and for both banks (Figures 29 and 32), the mean values are very close to zero. The right bank mean is that of deposition of only 48 ft of batture while the left bank mean is that of erosion of only

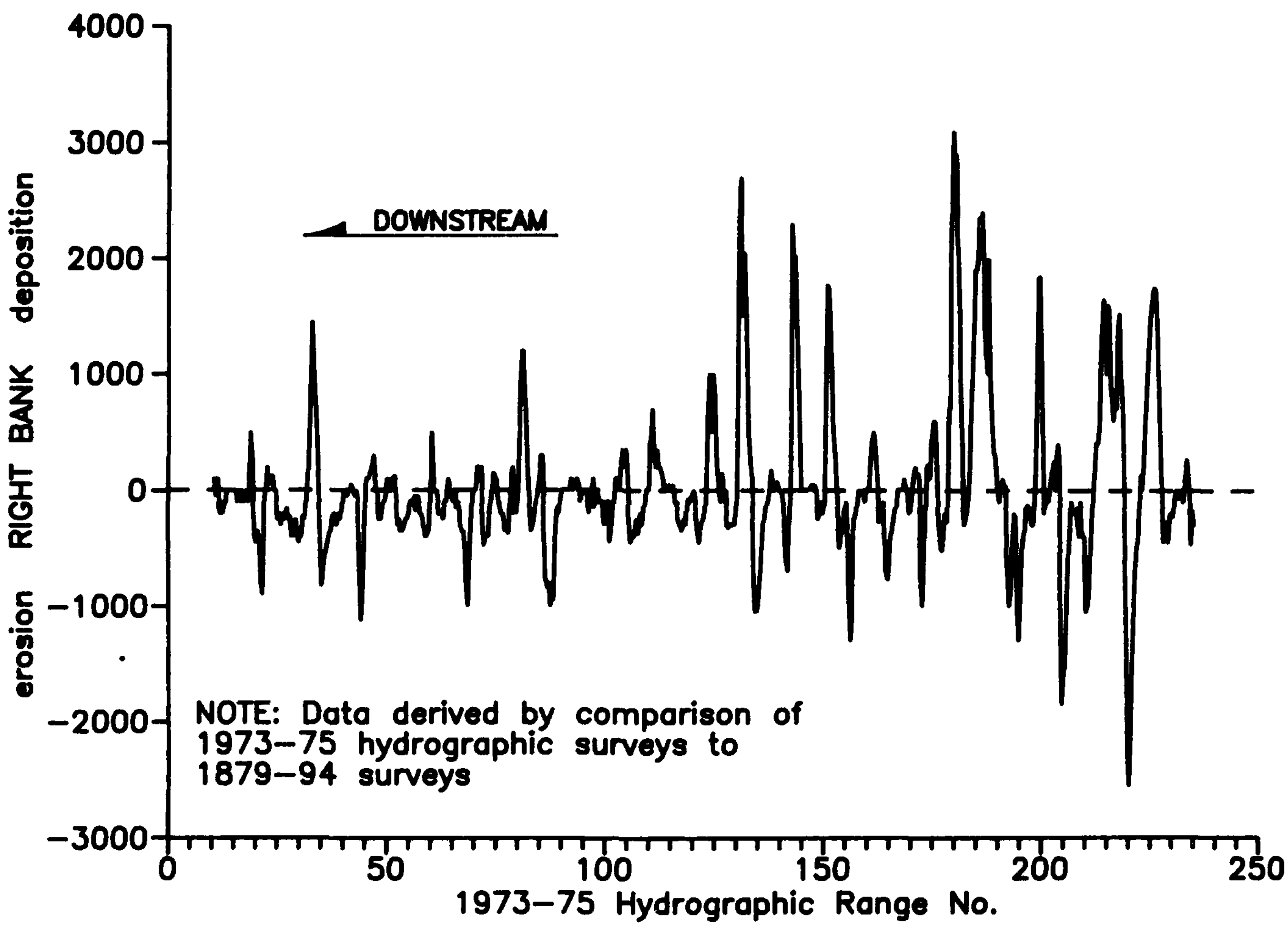


Figure 24. Historical erosion/deposition, right bank, Mississippi River, below Baton Rouge, LA

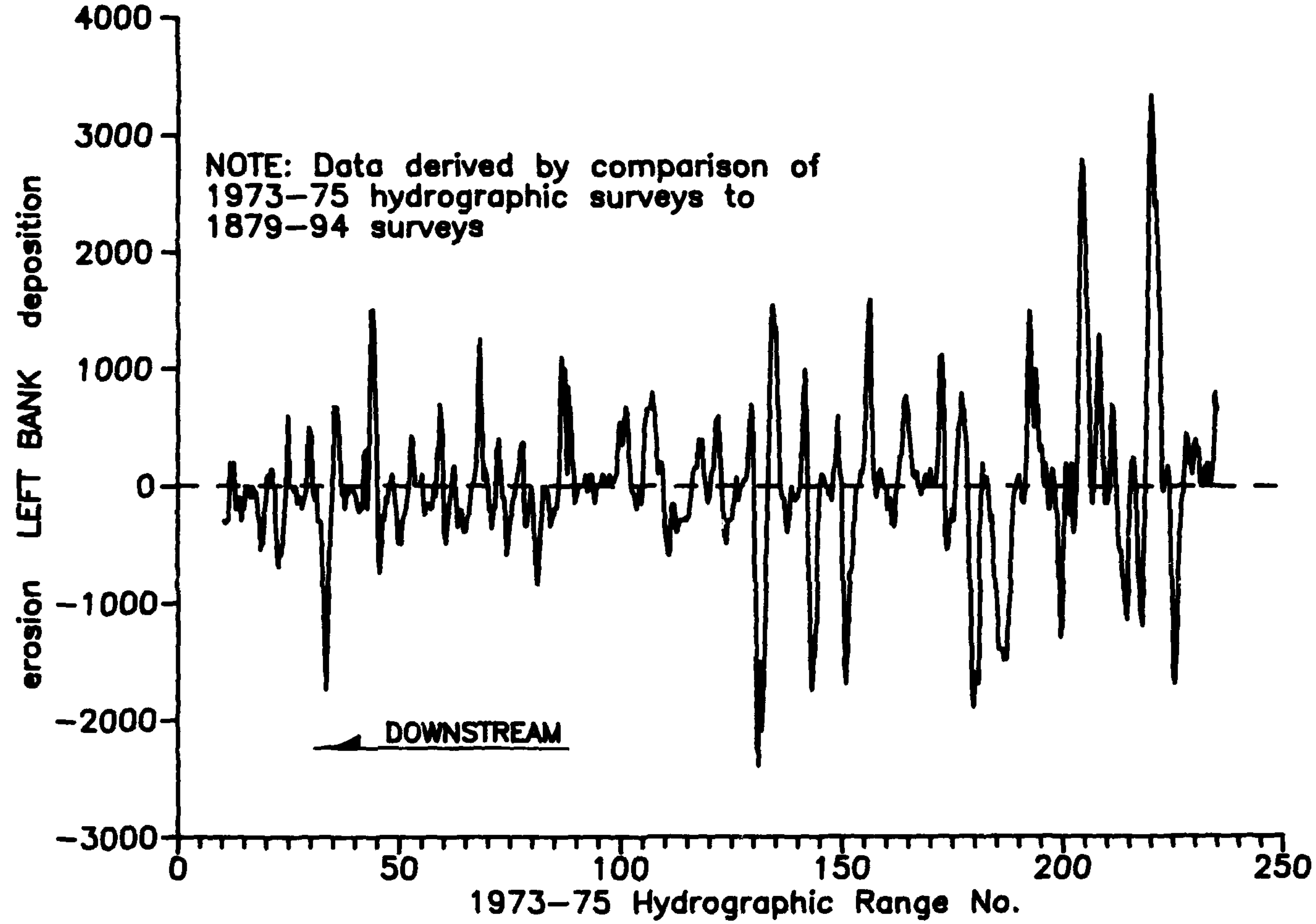


Figure 25. Historical erosion/deposition, left bank, Mississippi River, below Baton Rouge, LA

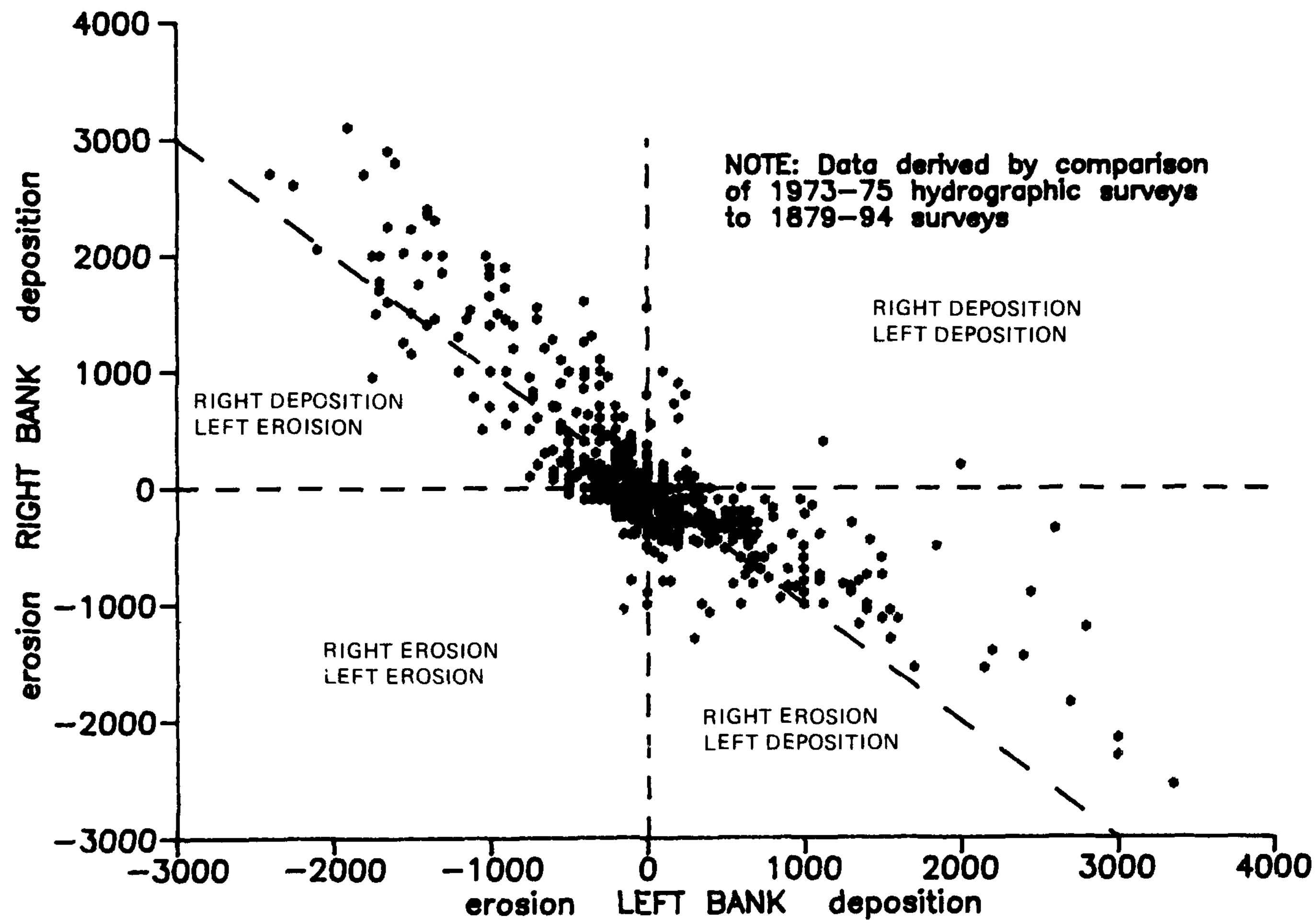


Figure 26. Historical erosion/deposition, right bank versus left bank, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

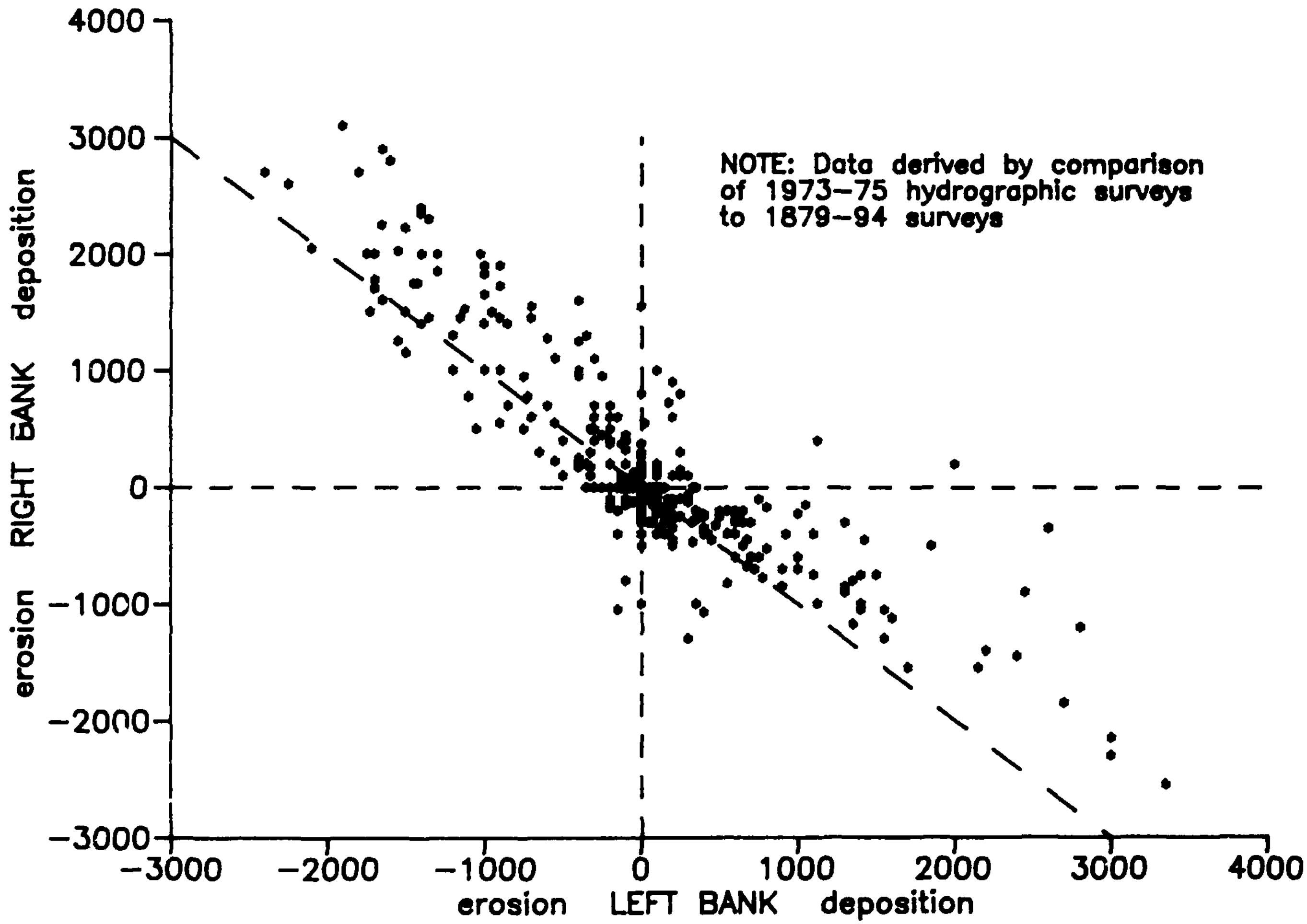


Figure 27. Historical erosion/deposition, right bank versus left bank, range 234.8 to 129.8, Mississippi River below Baton Rouge, LA

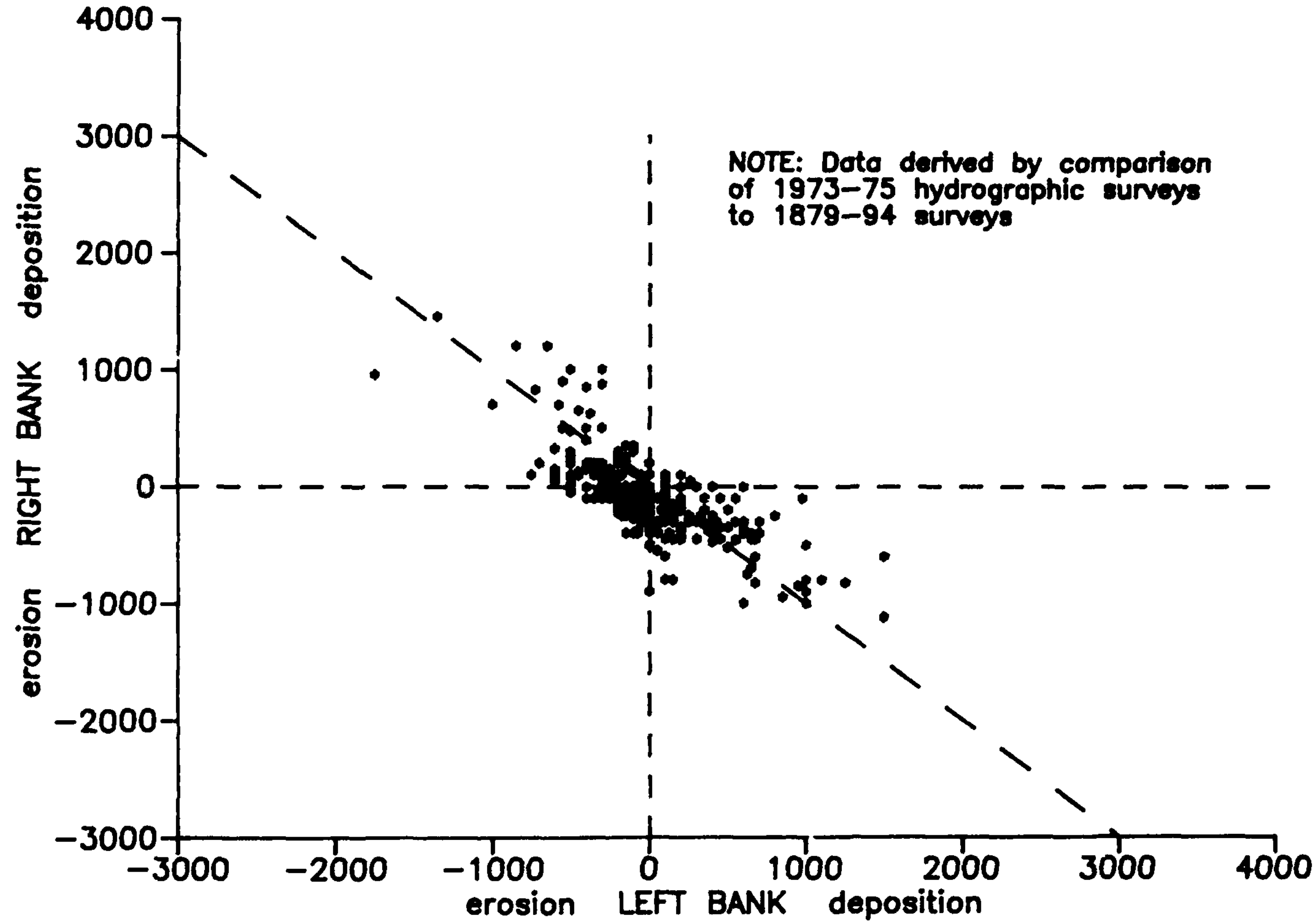


Figure 28. Historical erosion/deposition, right bank versus left bank, range 129.8 to 10.6, Mississippi River below Baton Rouge, LA

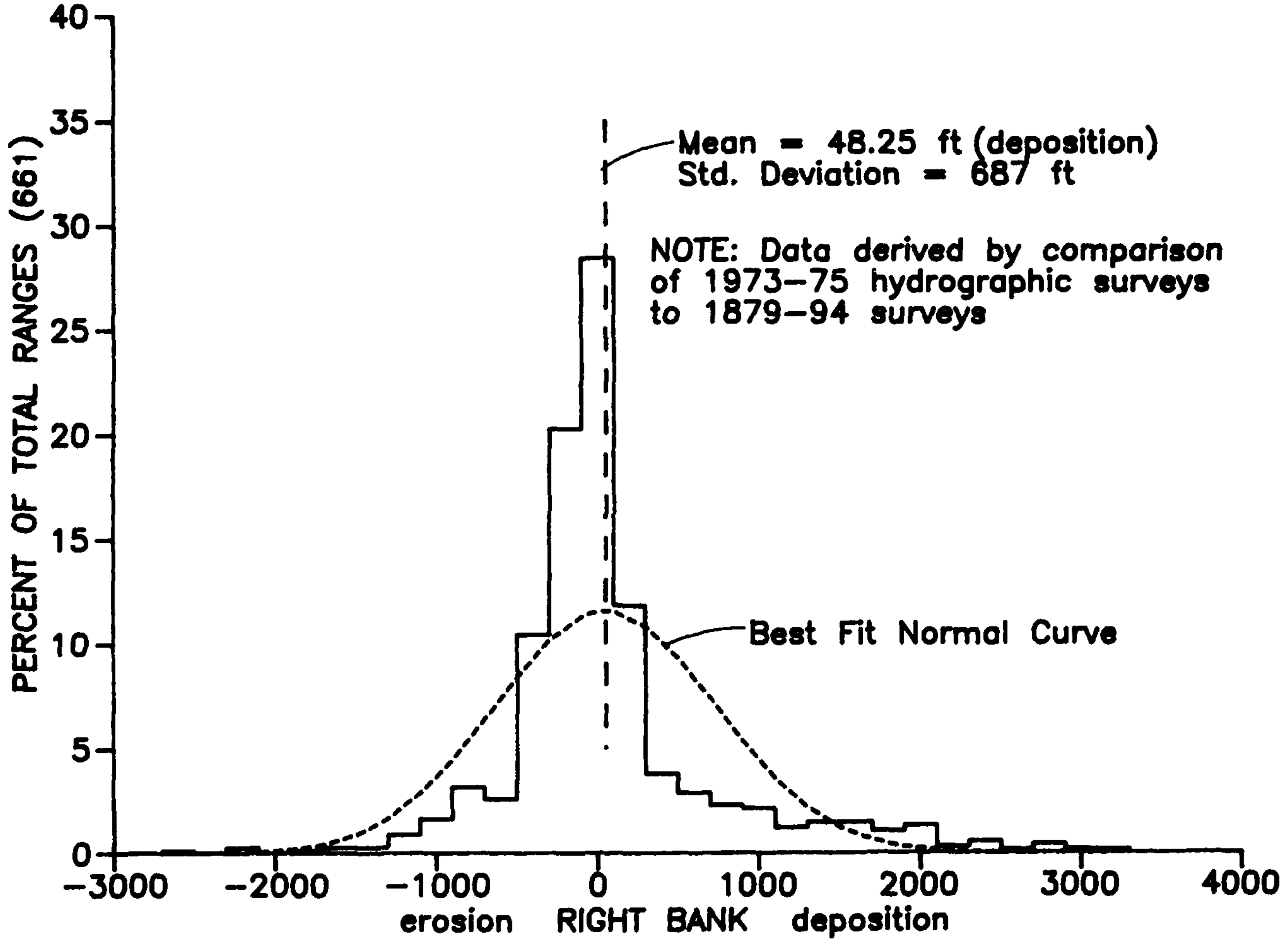


Figure 29. Frequency histogram, historical erosion/deposition, right bank, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

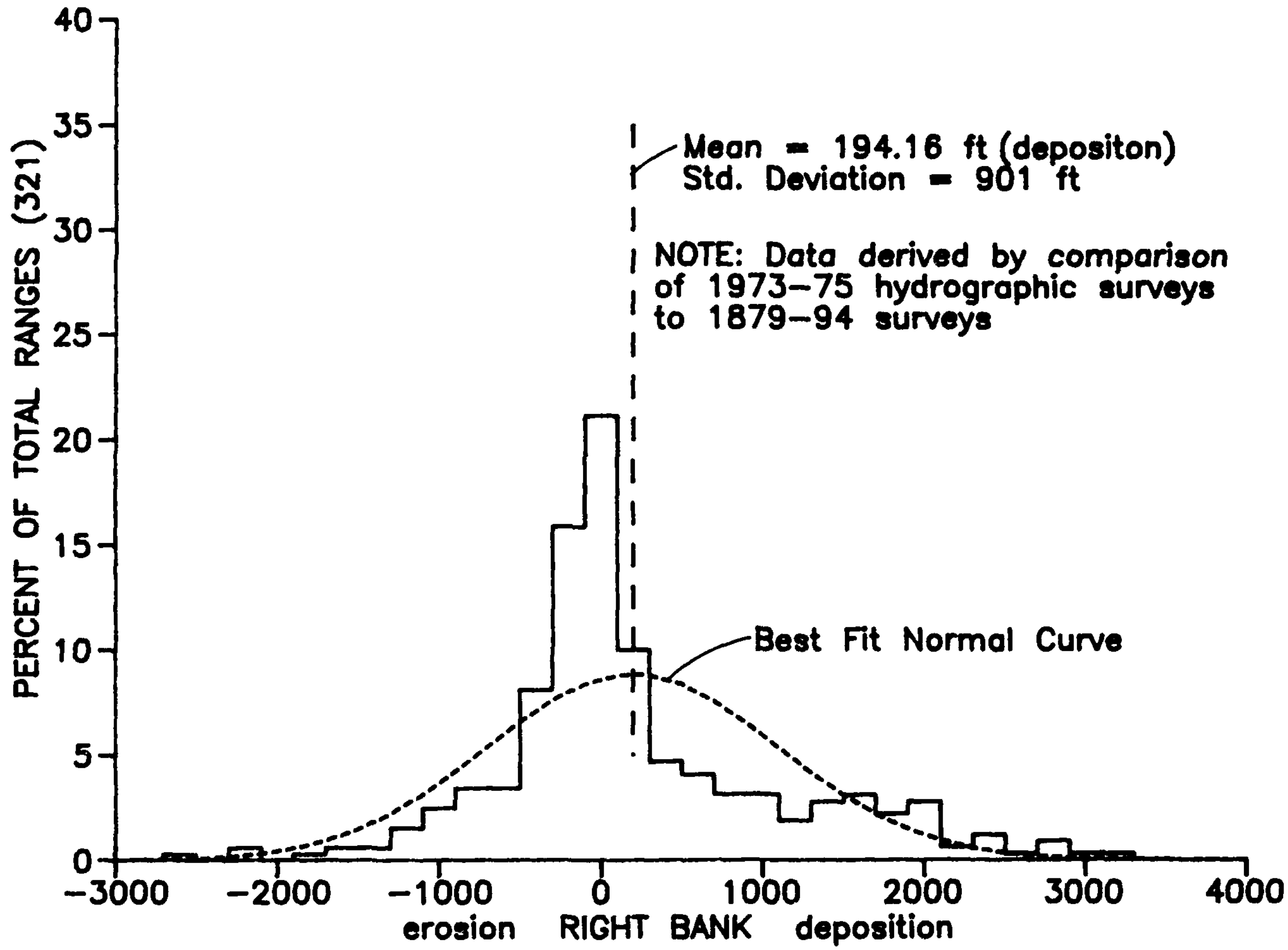


Figure 30. Frequency histogram, historical erosion/deposition, right bank, range 234.8 to 129.8, Mississippi River below Baton Rouge, LA

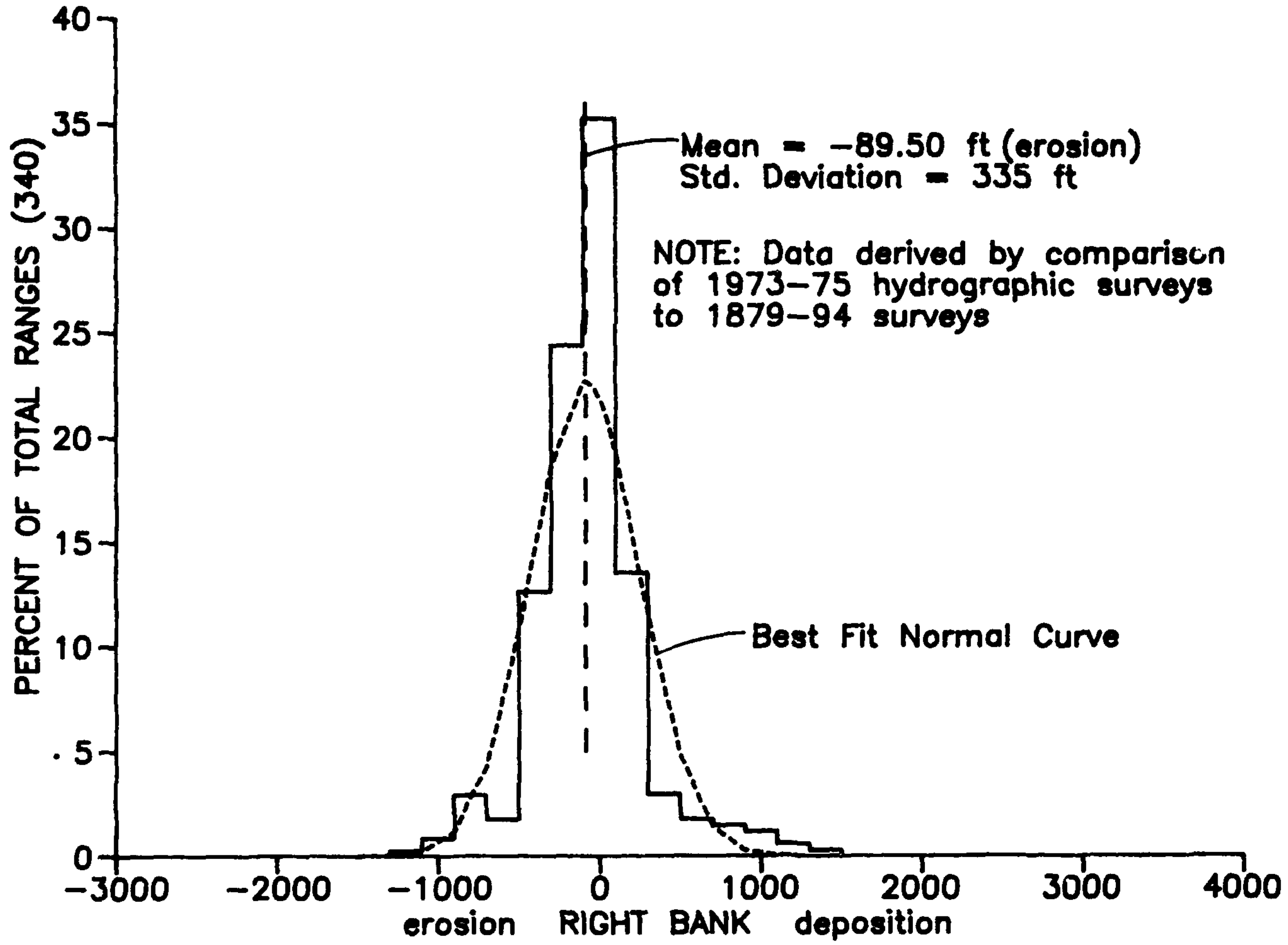


Figure 31. Frequency histogram, historical erosion/deposition, right bank, range 129.8 to 10.6, Mississippi River below Baton Rouge, LA

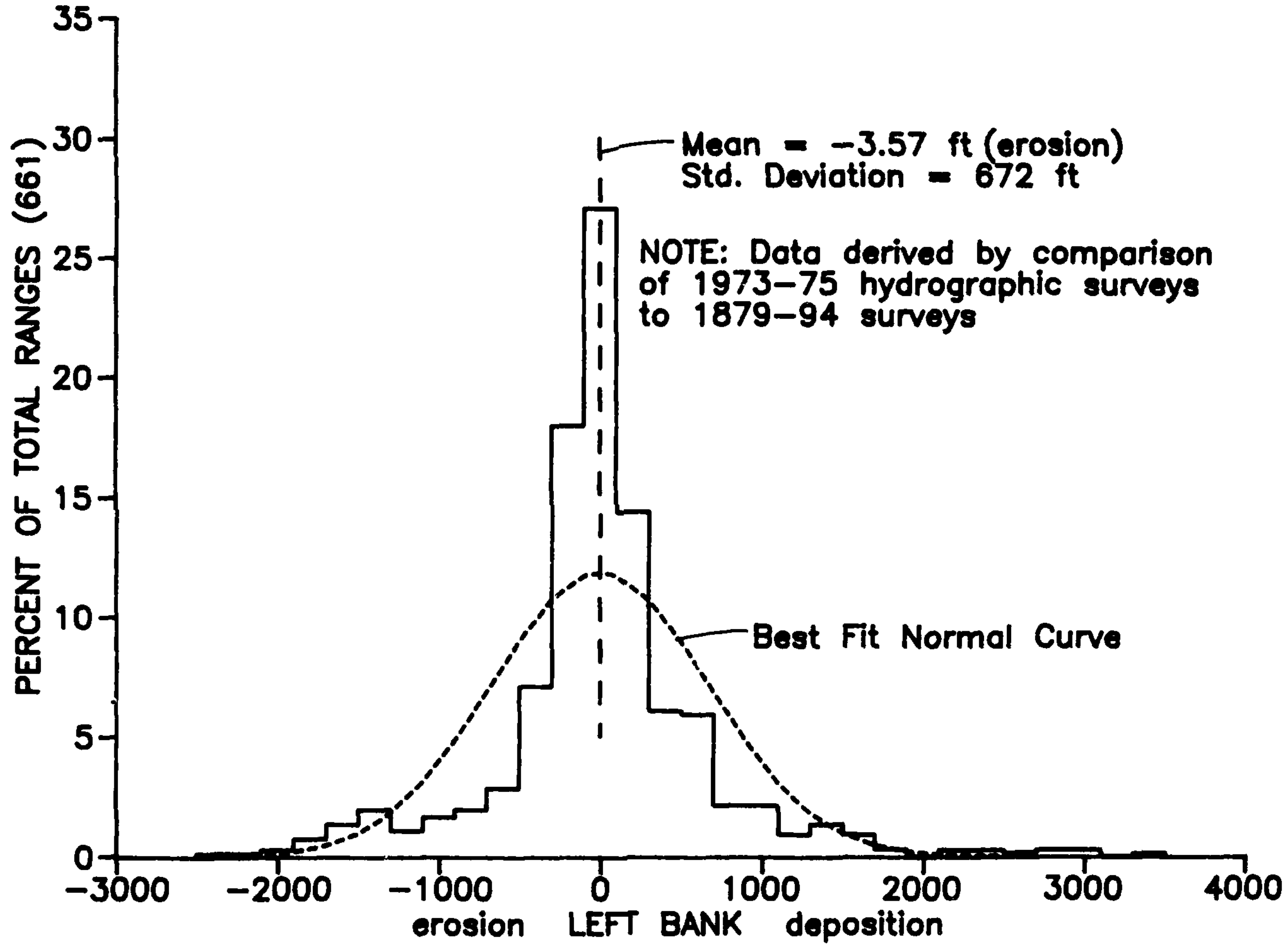


Figure 32. Frequency histogram, historical erosion/deposition, left bank, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

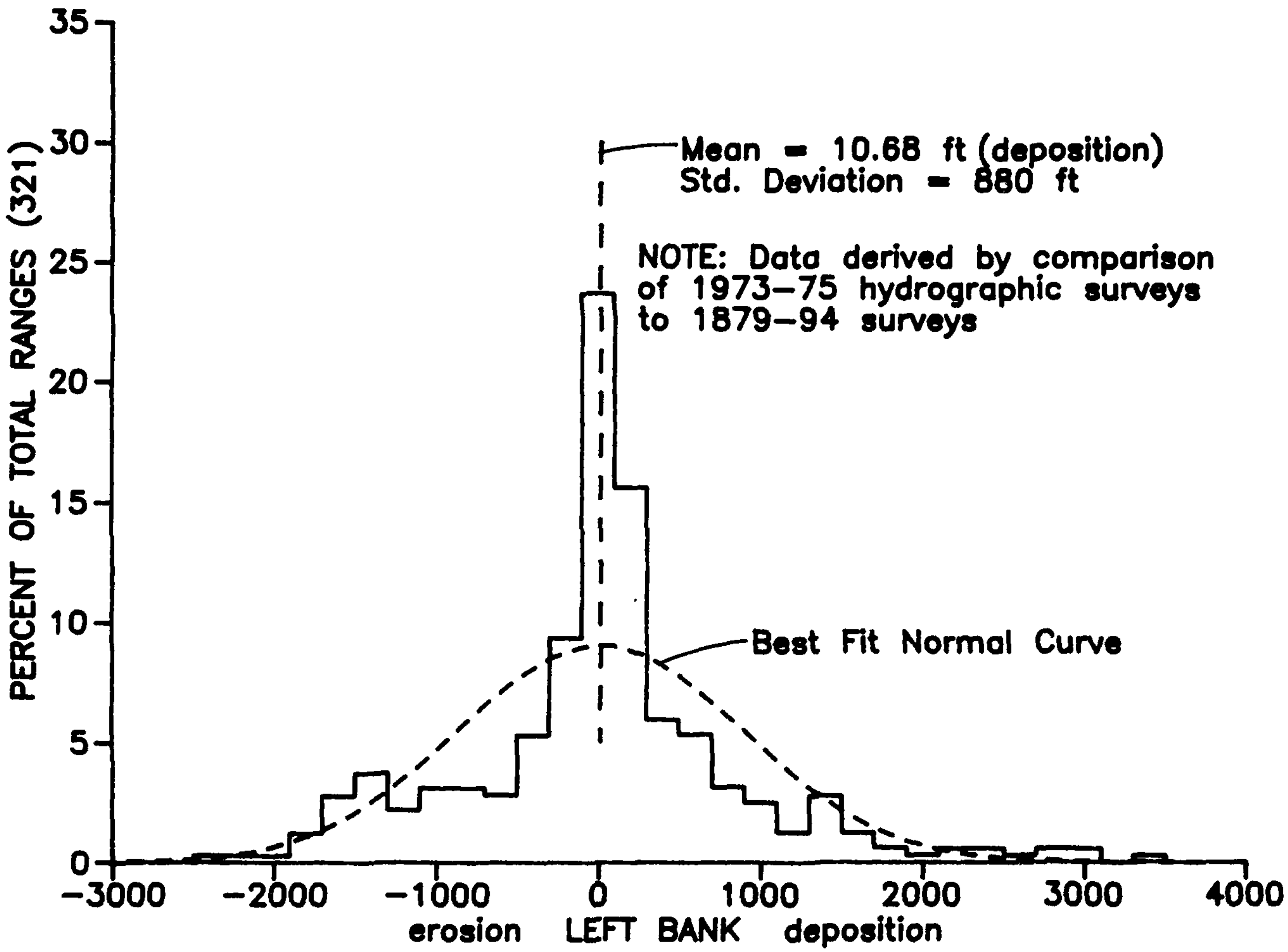


Figure 33. Frequency histogram, historical erosion/deposition, left bank, range 234.8 to 129.8, Mississippi River below Baton Rouge, LA

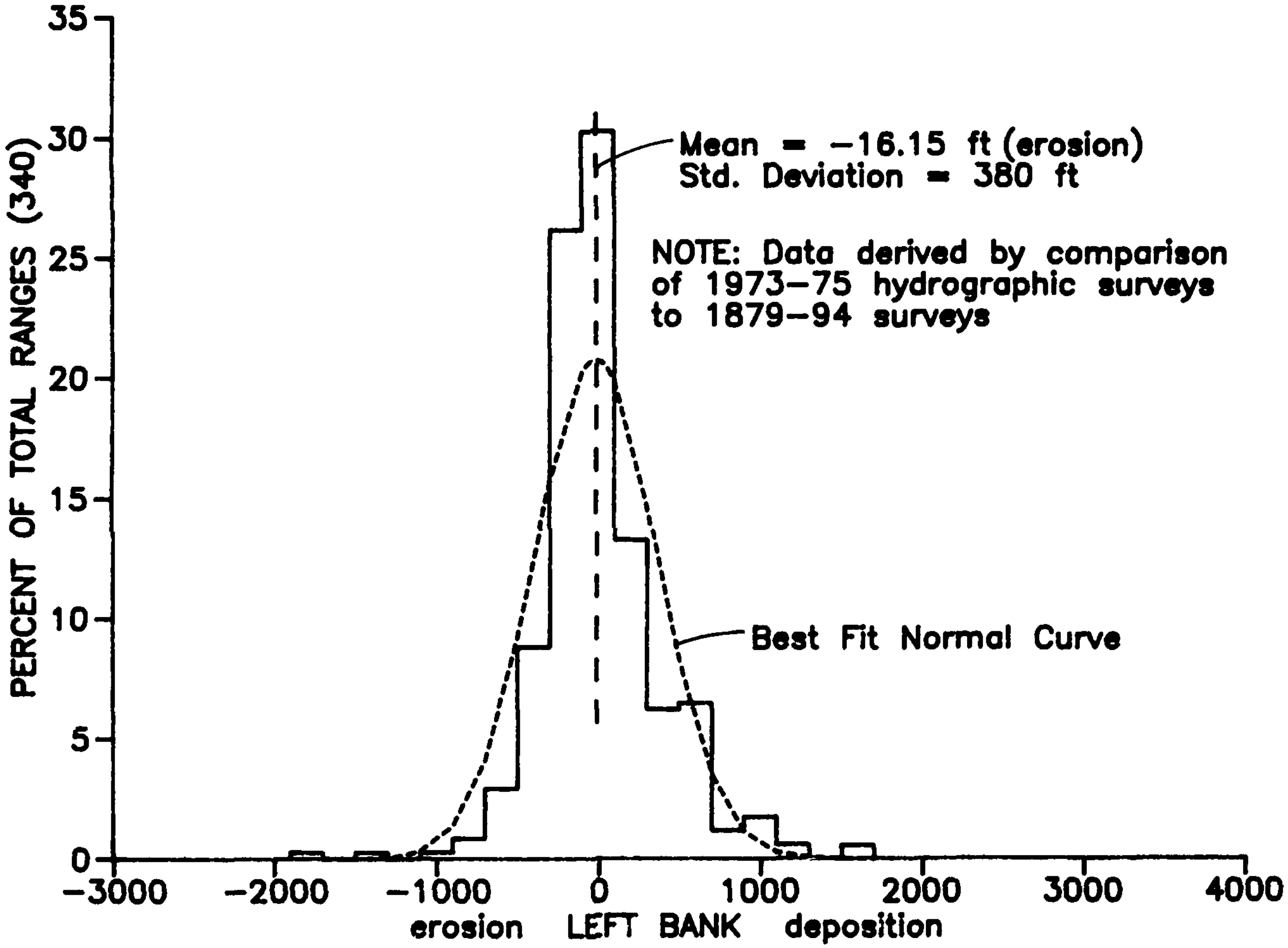


Figure 34. Frequency histogram, historical erosion/deposition, left bank, range 129.8 to 10.6, Mississippi River below Baton Rouge, LA

4 ft of batture. The distributions are relatively symmetrical about the means with essentially identical standard deviations although much more concentrated toward the means than normal distributions (Gaussian). For the largest percentage of the data for both banks, erosion falls in the "minor" category (less than 500 ft of historic batture loss).

b. When the total data sets are divided into the subsets above Bonnet Carre Spillway and below (right bank--Figures 30 and 31, left bank--Figures 33 and 34), the differences between the two reaches are again seen. The dispersions of the data for both banks above Bonnet Carre Spillway (hydrographic range R-129.8) are very similar (right bank standard deviation = 901 ft of batture; left bank standard deviation = 380 ft of batture). This reiterates the previous statement that the river has been much more active above Bonnet Carre Spillway than below. It is also seen that above R-129.8 the mean trend has been deposition for both banks, while below R-129.8 the mean trend has been erosion for both banks. Therefore, on the average, the river has tended to become narrower above Bonnet Carre Spillway but wider below.

41. Figures 35 and 36 show the changes in channel width and maximum depth, respectively, over the period of record. The changes in depth are based roughly (maximum error judged to be less than 5 ft between the old and latest surveys) on LWRP. The change in width shown in Figure 35 exhibits a clear trend from upstream to downstream in that the river has tended to transition from becoming narrower to becoming wider with the crossover point again being near Bonnet Carre Spillway. This trend is not favorable since Figure 36 reveals that very little significant changes have occurred with respect to depth. If the river remains at the same depth above R-129.8 while it tends to become narrower in that same reach, it portends increasing average current velocities. This will cause trouble where erosion/scour hole formation, general bank stability, and flow slide problems are concerned. In addition, the tendency of the river to slowly widen below R-129.8 portends bank caving problems mostly in the "minor" category but, nonetheless, relentless. These trends just indicate that there is no relief in sight, and that the problems are likely to multiply.

42. Frequency histograms for the change in channel width are given in Figures 37-39 and for change in channel depth in Figures 40-42. The change-in-width histograms illustrate the trends addressed above. The change-in-depth histograms show strong normal distribution tendencies and reveal how little depth has changed over the total period of record. For the total reach of river below Baton Rouge, over 90 percent of the ranges reflected a change

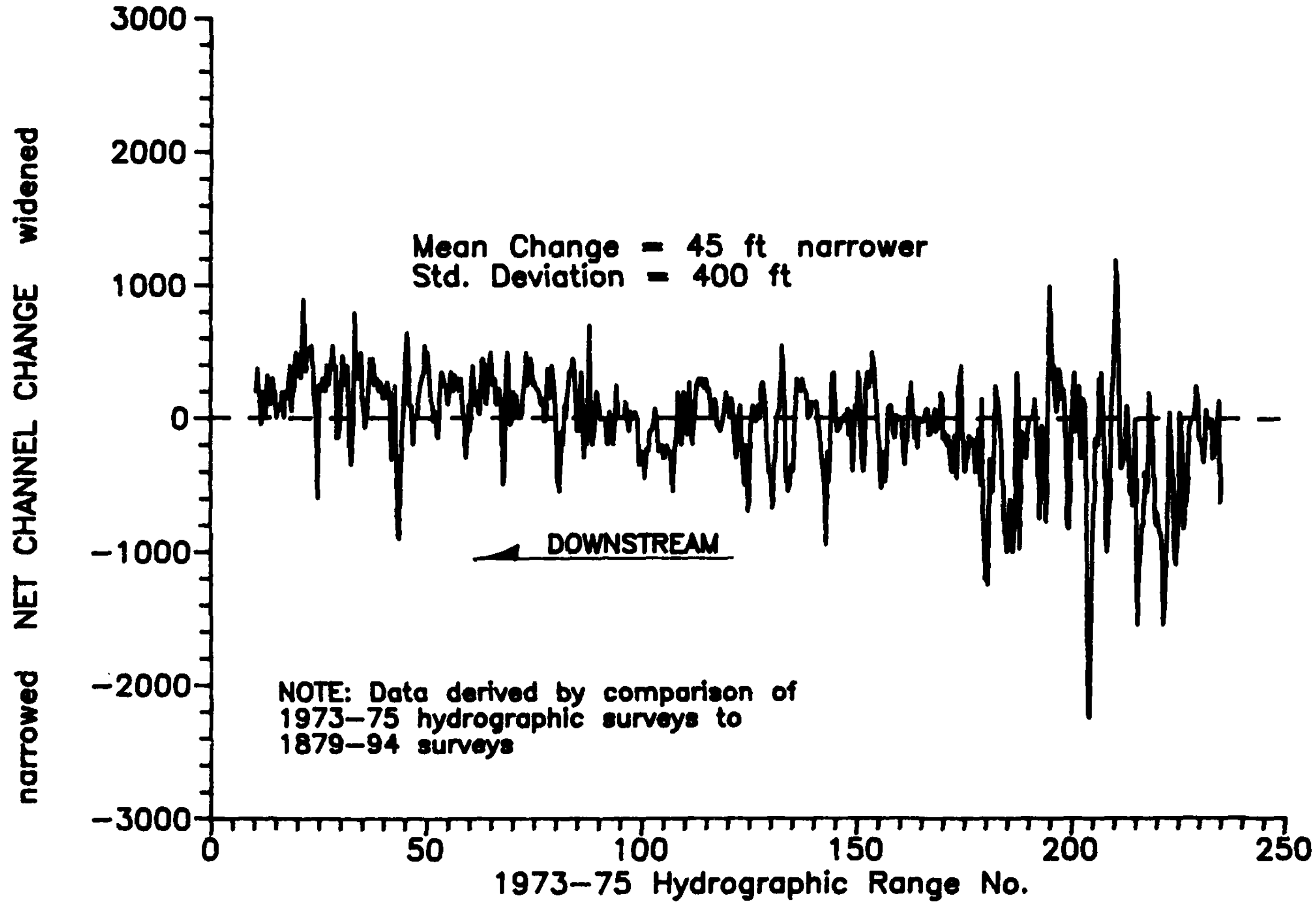


Figure 35. Historical change in channel width, Mississippi River below Baton Rouge, LA

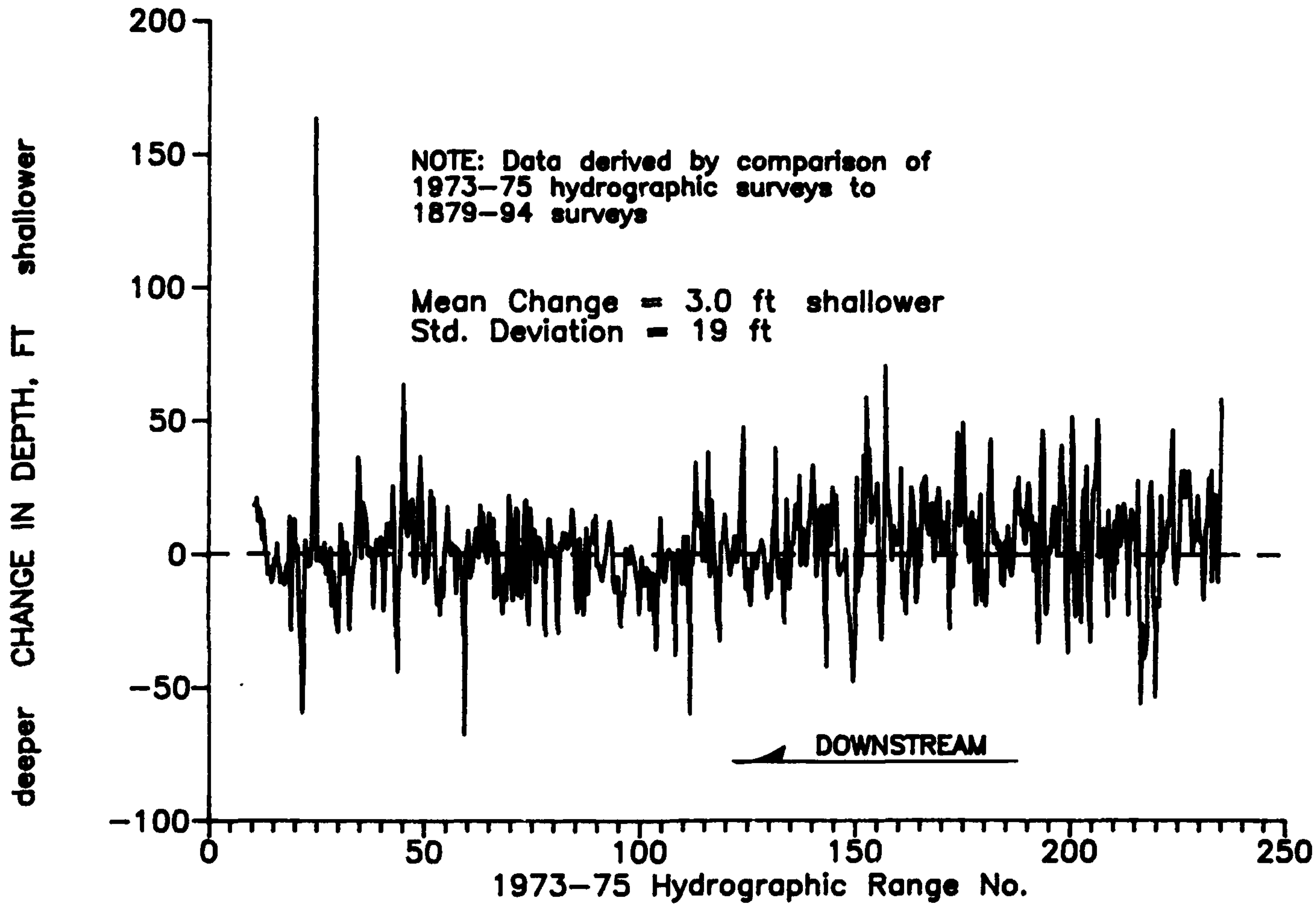


Figure 36. Historical change in channel depth, Mississippi River below Baton Rouge, LA

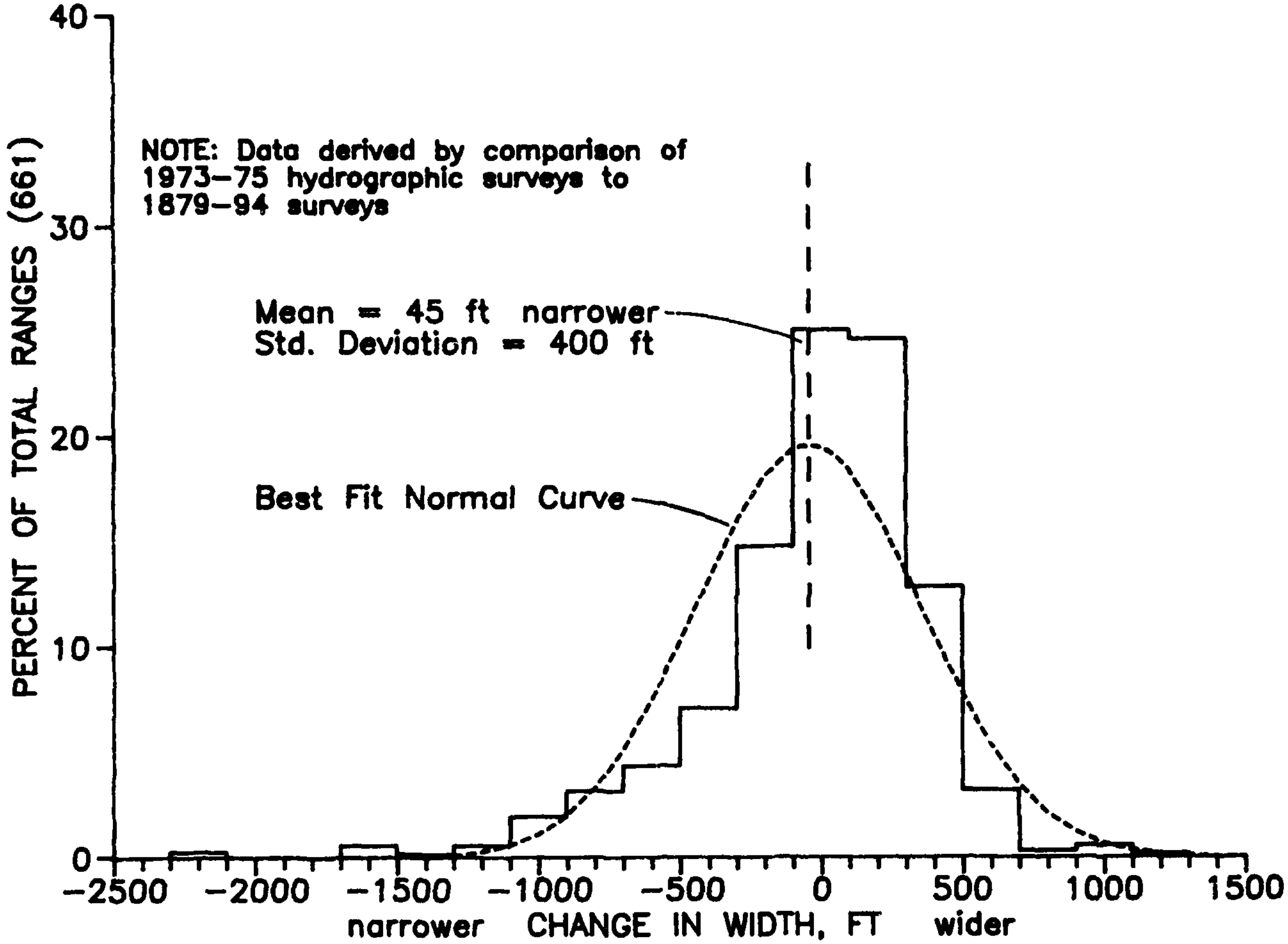


Figure 37. Frequency histogram, change in channel width, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

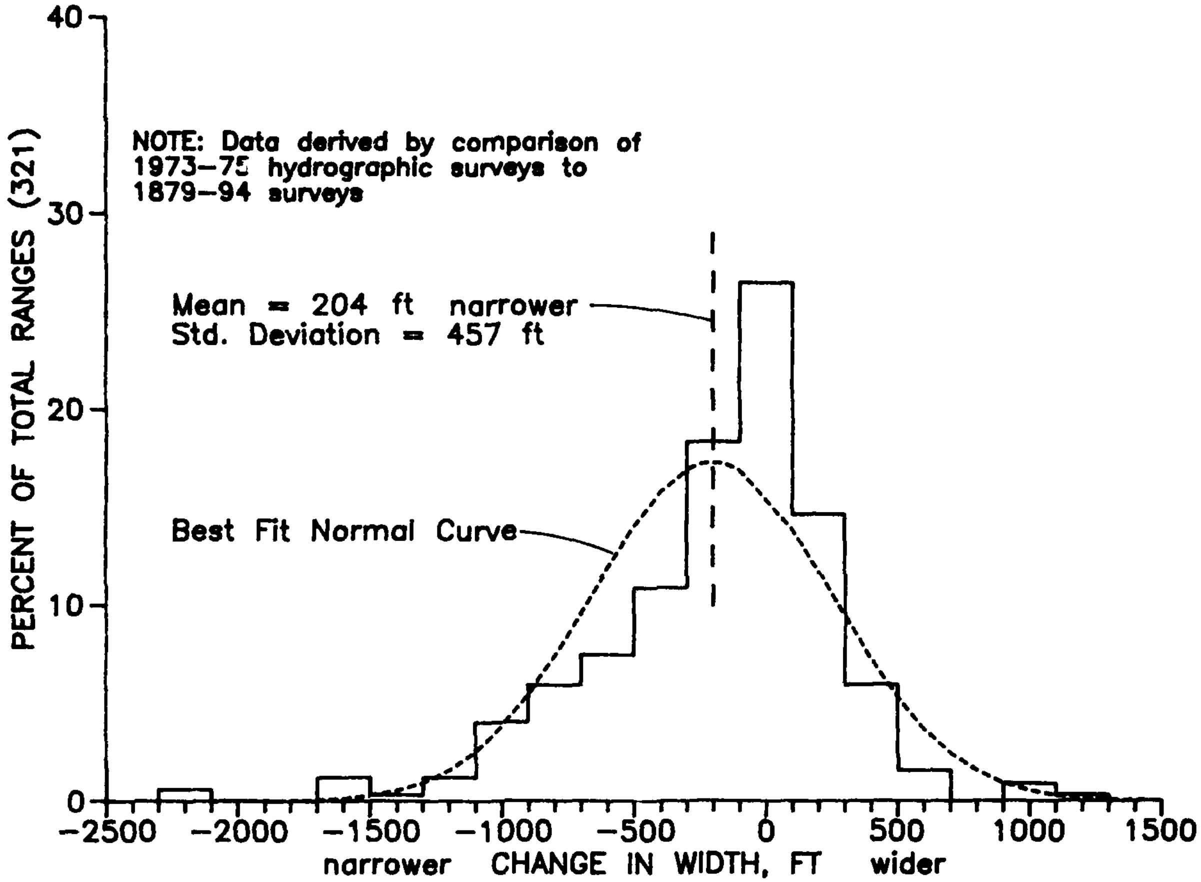


Figure 38. Frequency histogram, change in channel width, range 234.8 to 129.8, Mississippi River below Baton Rouge, LA

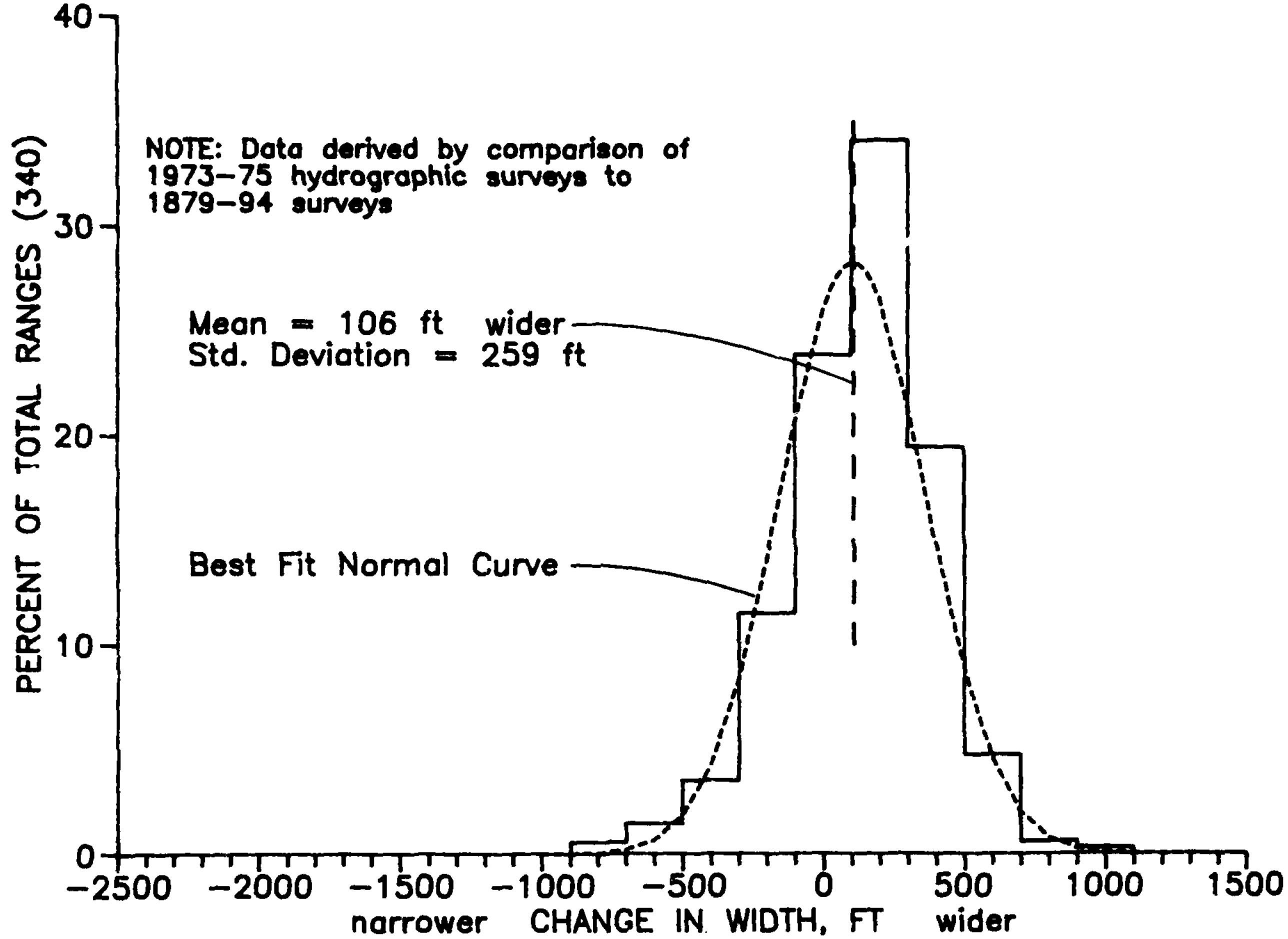


Figure 39. Frequency histogram, change in channel width, range 129.8 to 10.6, Mississippi River below Baton Rouge, LA

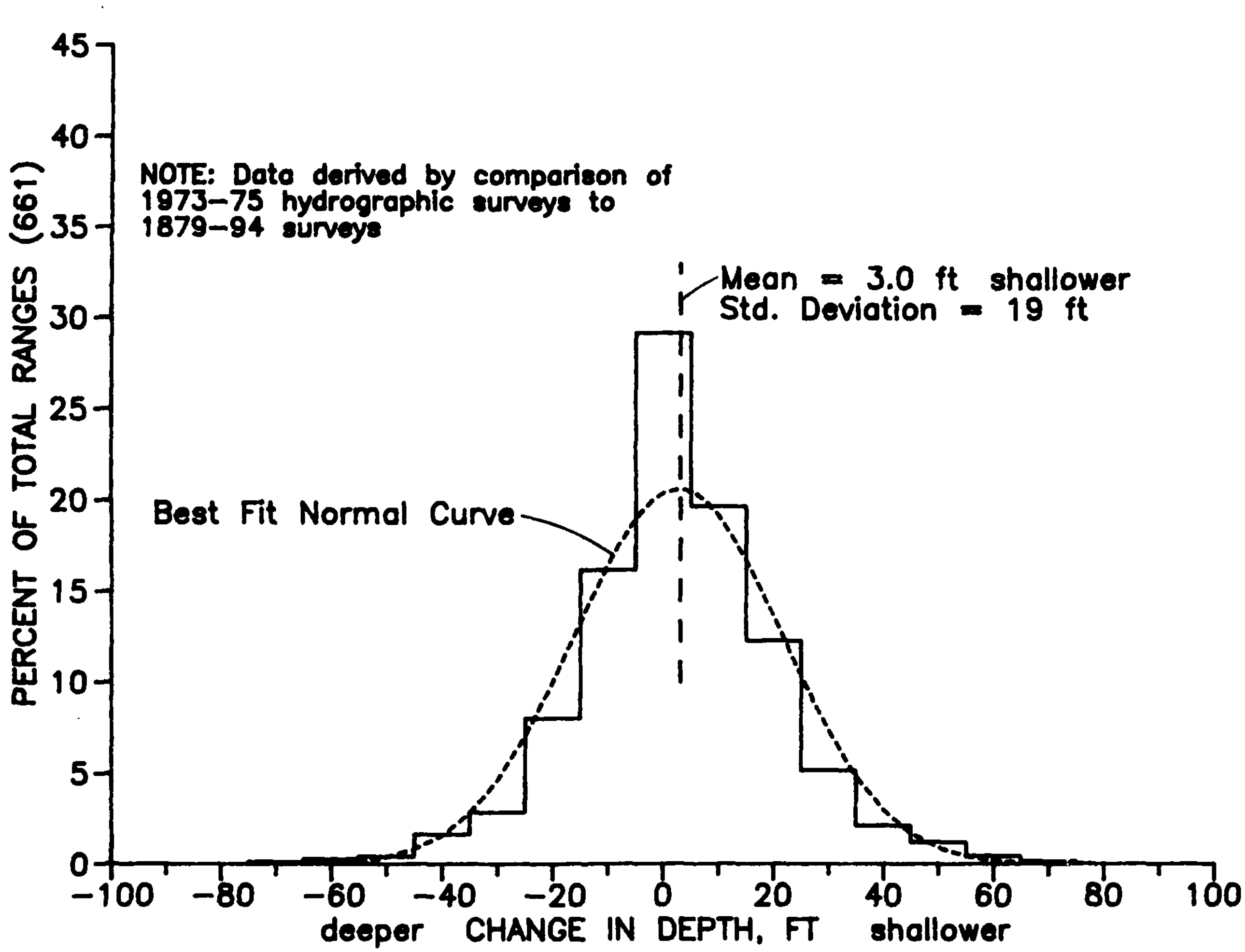


Figure 40. Frequency histogram, change in channel depth, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

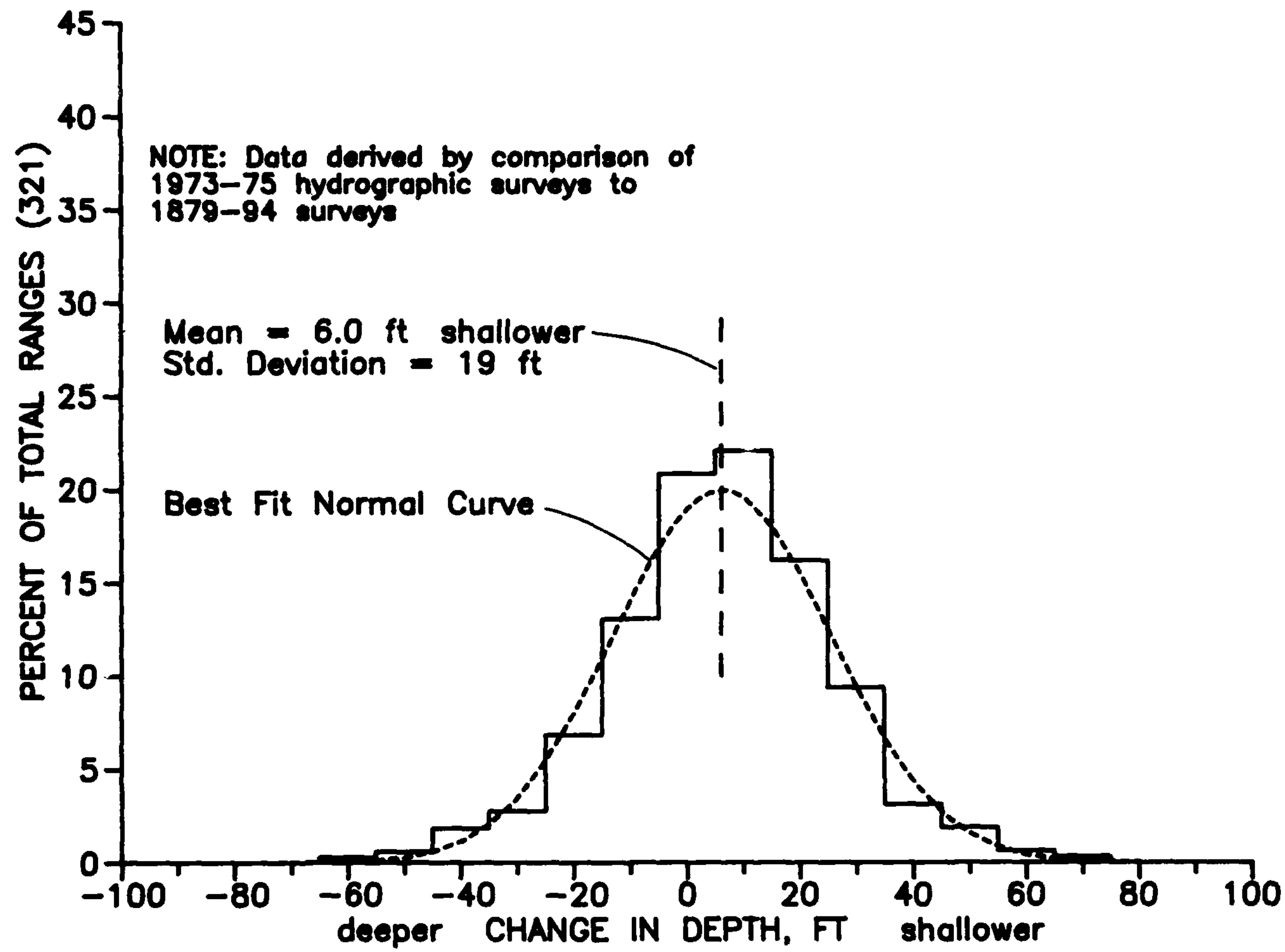


Figure 41. Frequency histogram, change in channel depth, range 234.8 to 129.8, Mississippi River below Baton Rouge, LA

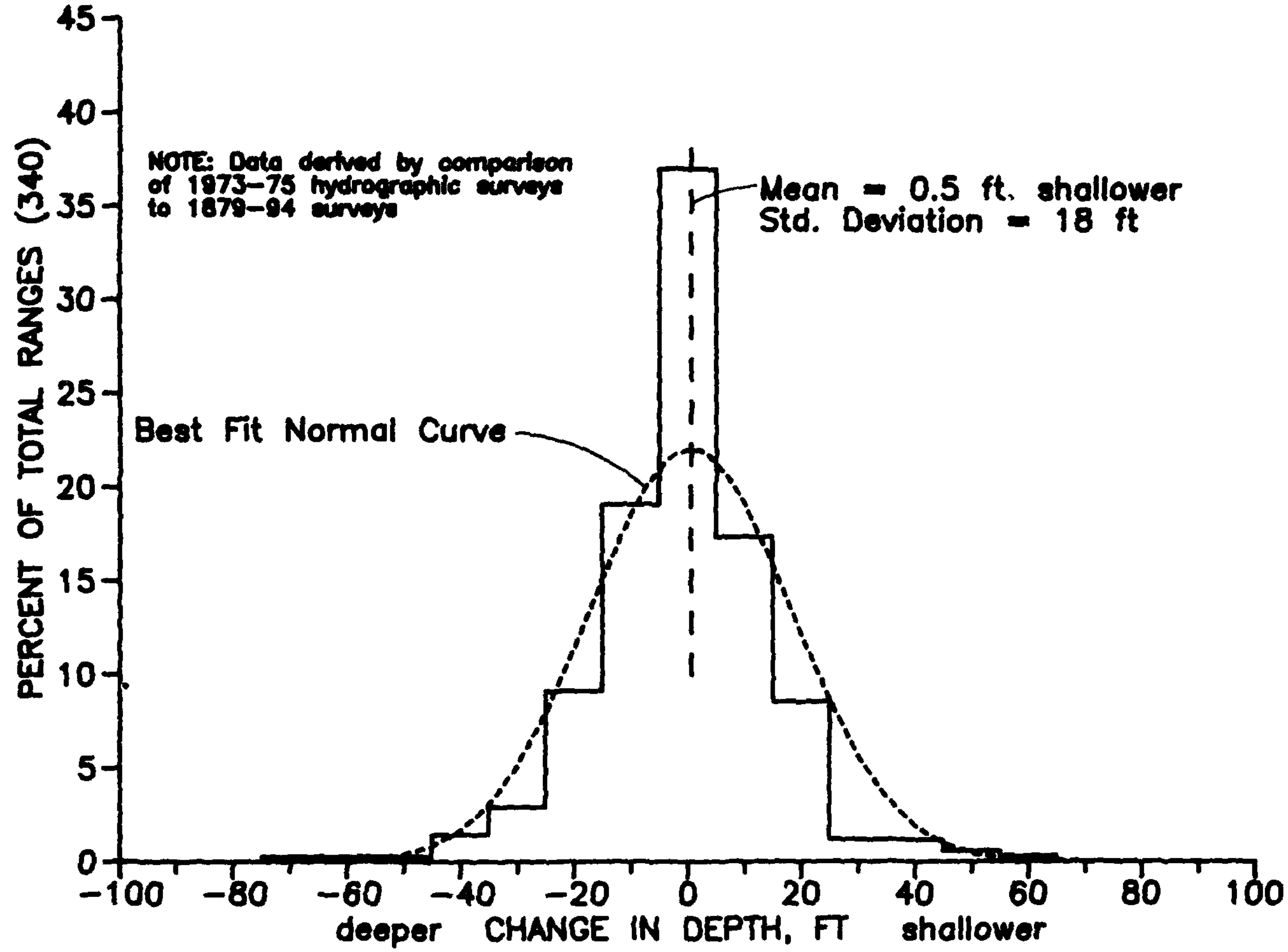


Figure 42. Frequency histogram, change in channel depth, range 129.8 to 10.6, Mississippi River below Baton Rouge, LA

in depth of less than 30 ft in either direction. Considering the fact that such variations and larger are not uncommon on an annual basis (attributable to bottom sand waves or scour-fill cycles), it appears to be safe to say that only the rare events of changes in excess of 50 ft are significant. Only about 2 percent (16 of 661) of the range locations showed changes in depth either deeper or shallower in excess of 50 ft.

Statistical Summary of 1973-1975 River Parameters

43. Channel width and maximum depth were determined for all 1973-1975 hydrographic ranges (1328) from R-234.8 (Baton Rouge) to R-10.6 (end of mainline levees). The ratios of width to maximum depth (W/D) and the channel triangular cross-sectional areas (WD/2) were also calculated. These numbers are not intended to provide anything other than very rough pictures and have very little use in the rigorous potamology sense. Other parameters such as effective area or hydraulic radius might be more useful, but perhaps the data given herein will indicate the potential worth of studying the more applicable numbers. Channel width, channel maximum depth, range in W/D ratio, and range in channel triangular area are plotted in Figure 43. The figure shows that there is little correlation between width and depth other than a very muted trend for width to increase as depth decreases. Channel area ranges from as low as only about 50,000 sq ft to as much as six times that value. At the same time, W/D varies from less than 10 to over 100. Attempts to discern the nature of such variance, much less to make predictions of behavior on a site-by-site basis, are monumental undertakings. Nonetheless, the author believes that comprehensive study of the river below Baton Rouge will force itself upon the problem solution sooner or later; it might as well be accepted now and begun. Even if a cost effective preventative bank protection system is developed in the meantime, it is hard to imagine that funds expended in gaining additional knowledge of the river will prove to be a poor investment.

44. The discrete data for width, depth, W/D ratio, and triangular area are plotted in Figure 44-47, respectively. Corresponding frequency histograms are given in Figures 48-51. Figure 44 shows a slight tendency for the average channel width to be larger at both ends of the reach below Baton Rouge and for pronounced amplitude in width variation in the upstream half (R-234.8 to R-110.0) of the reach. Channel depth shown in Figure 45 tends to steadily

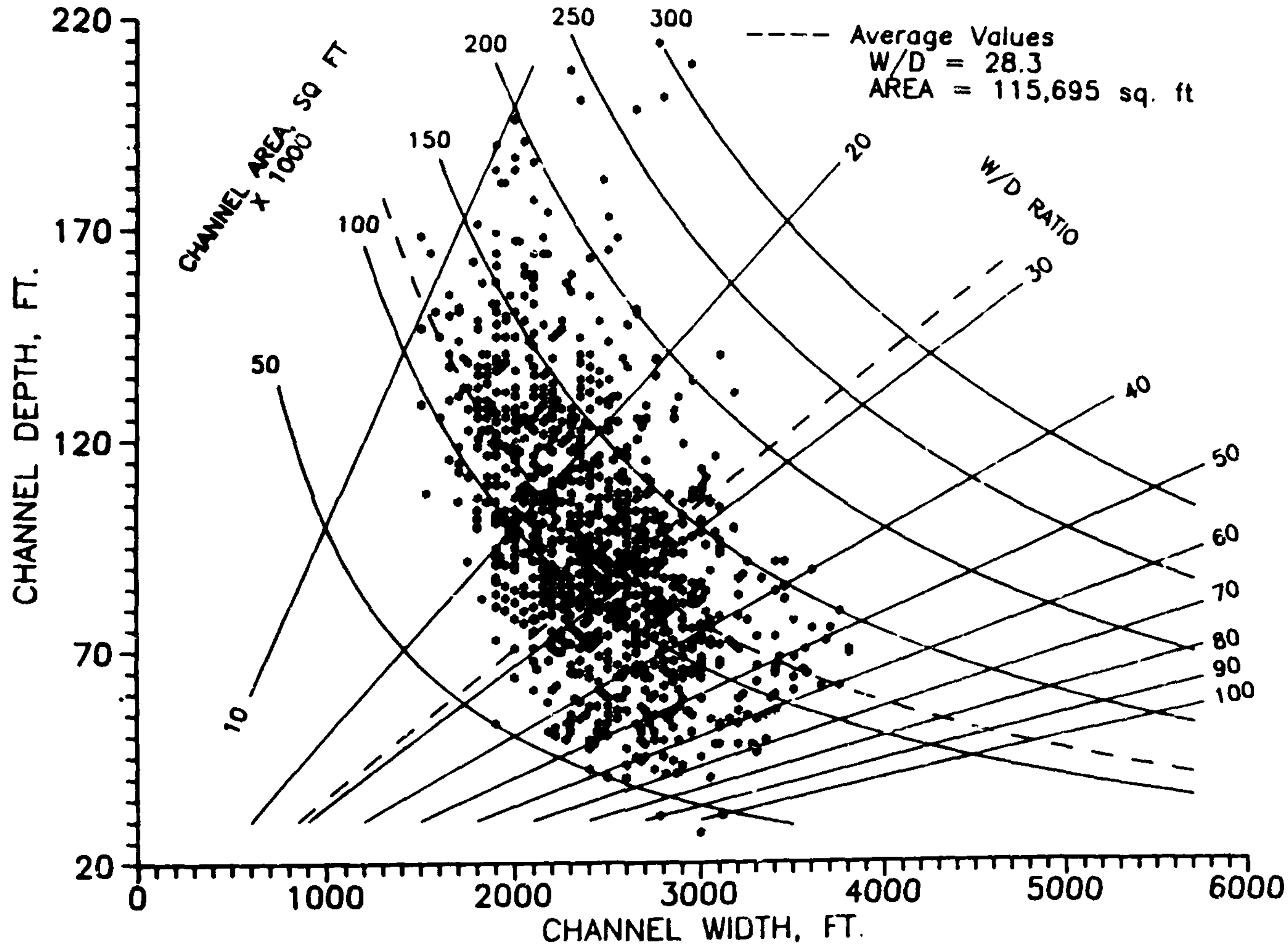


Figure 43. Channel depth, channel width, channel triangular area, and W/D ratio, Mississippi River below Baton Rouge, LA, 1973-1975 hydrographic survey

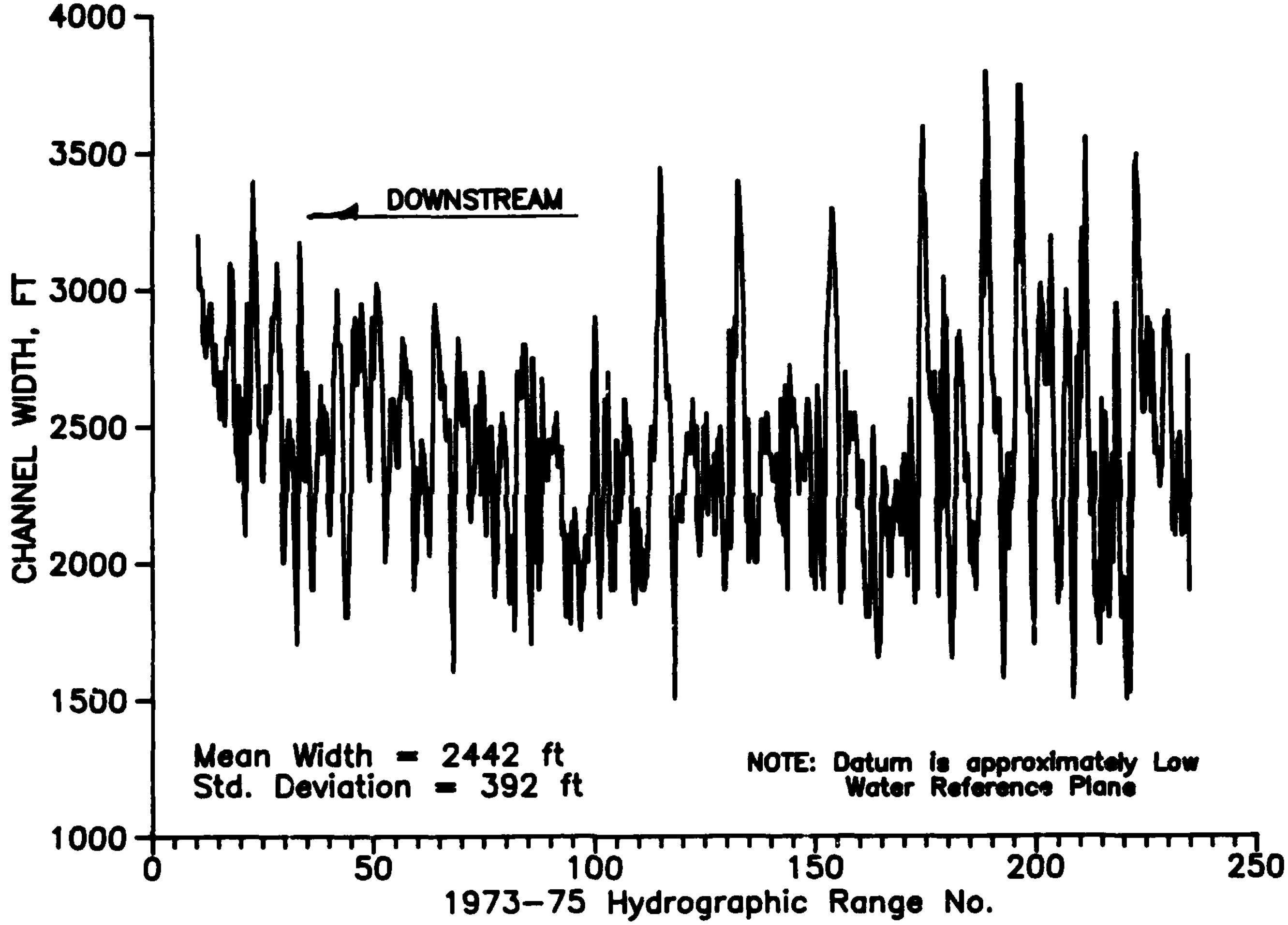


Figure 44. Channel width, Mississippi River below Baton Rouge, LA, 1973-1975 hydrographic survey

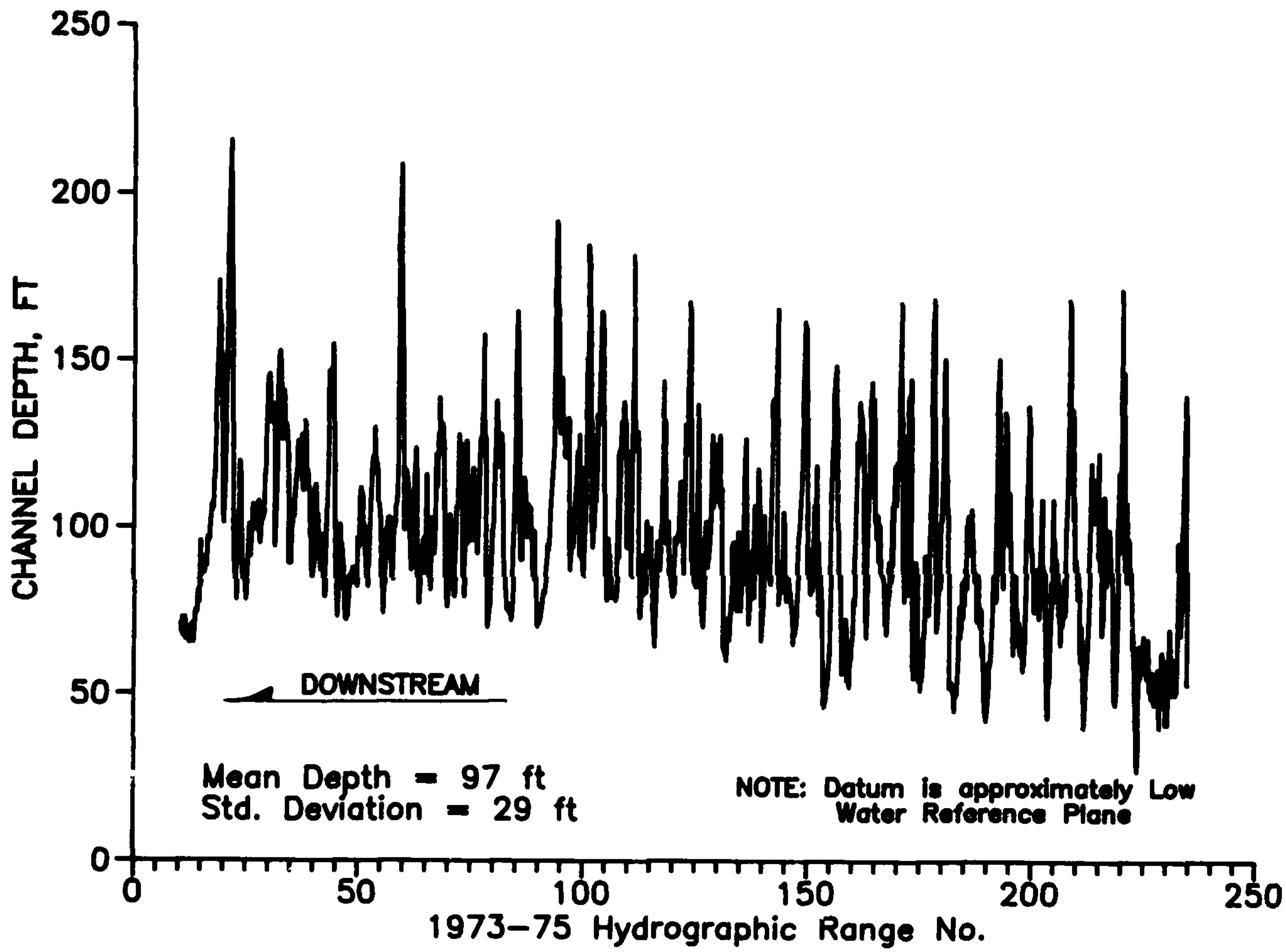


Figure 45. Channel depth, Mississippi River below Baton Rouge, LA, 1973-1975 hydrographic survey

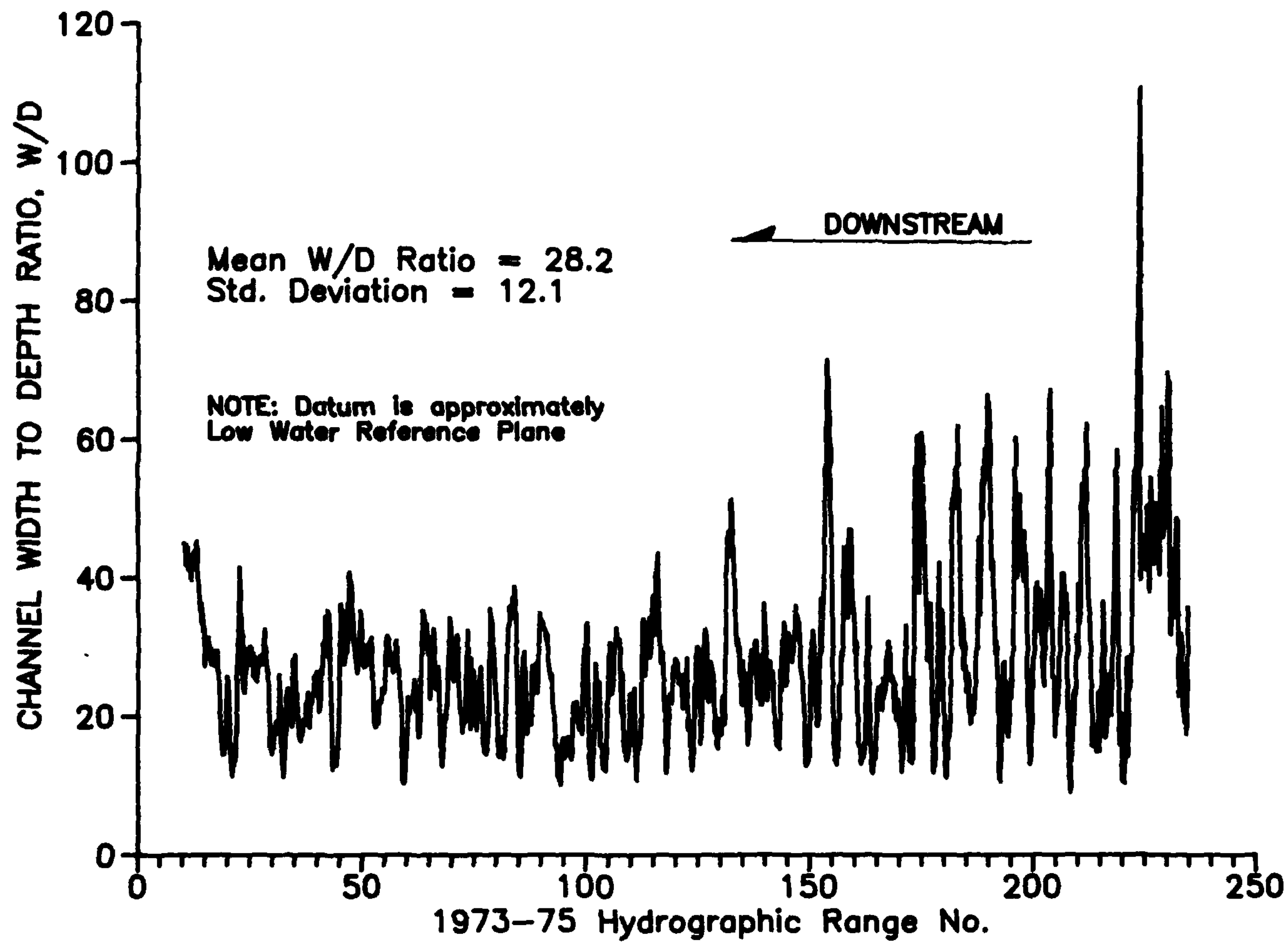


Figure 46. Channel W/D ratio, Mississippi River below Baton Rouge, LA, 1973-1975 hydrographic survey

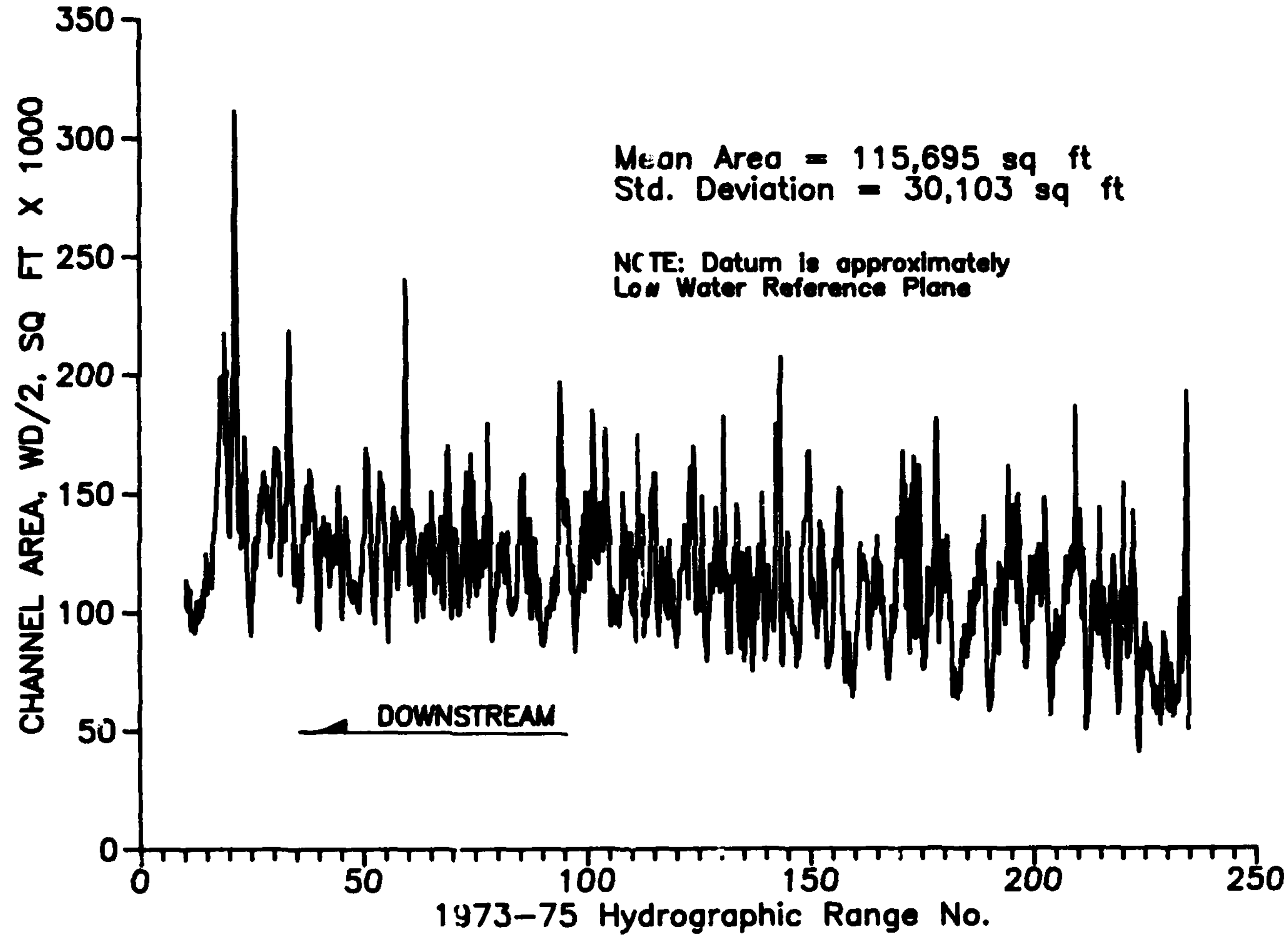


Figure 47. Channel triangular cross-sectional area, Mississippi River below Baton Rouge, LA, 1973-1975 hydrographic survey

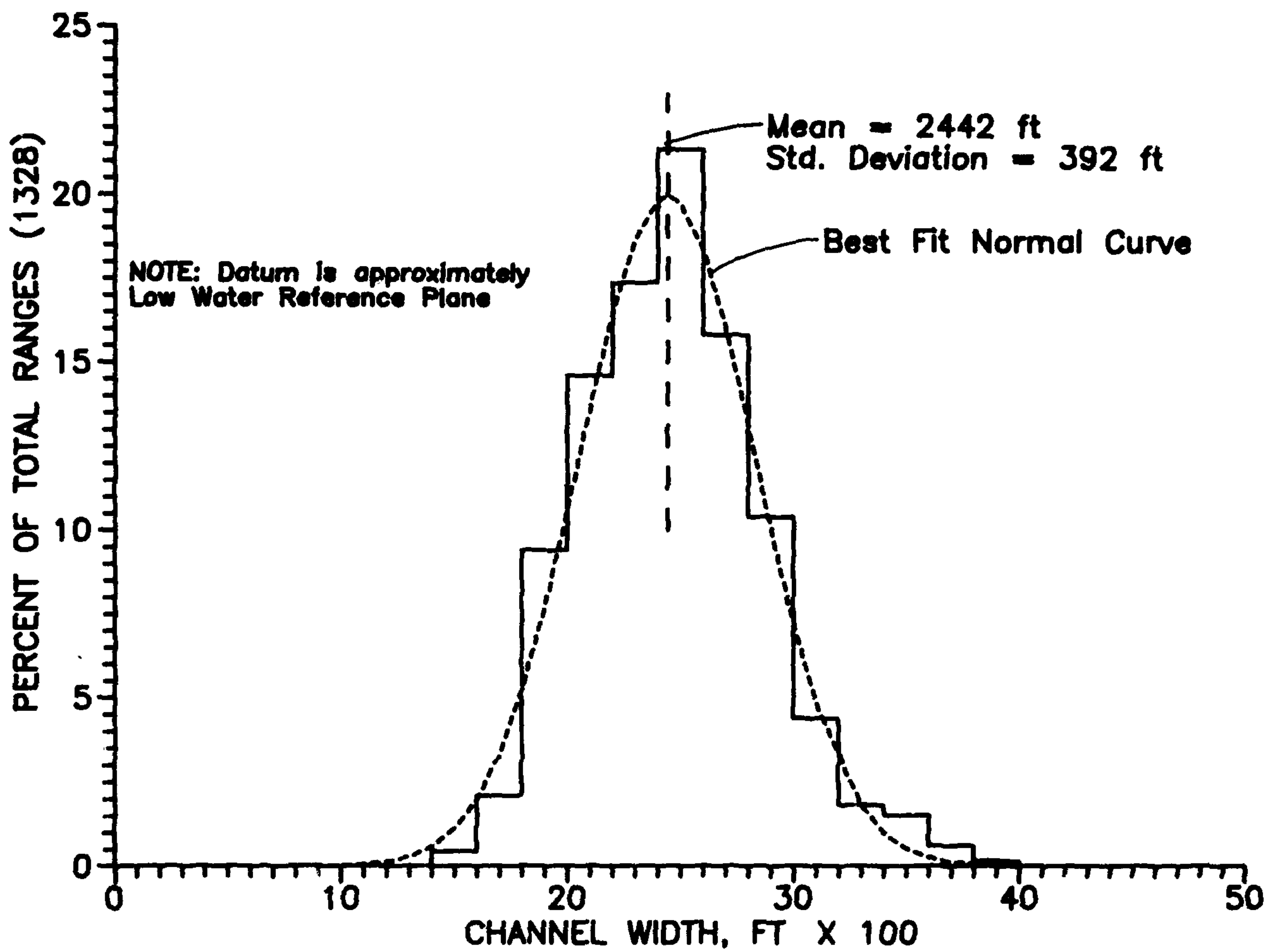


Figure 48. Frequency histogram, 1973-1975 channel width, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

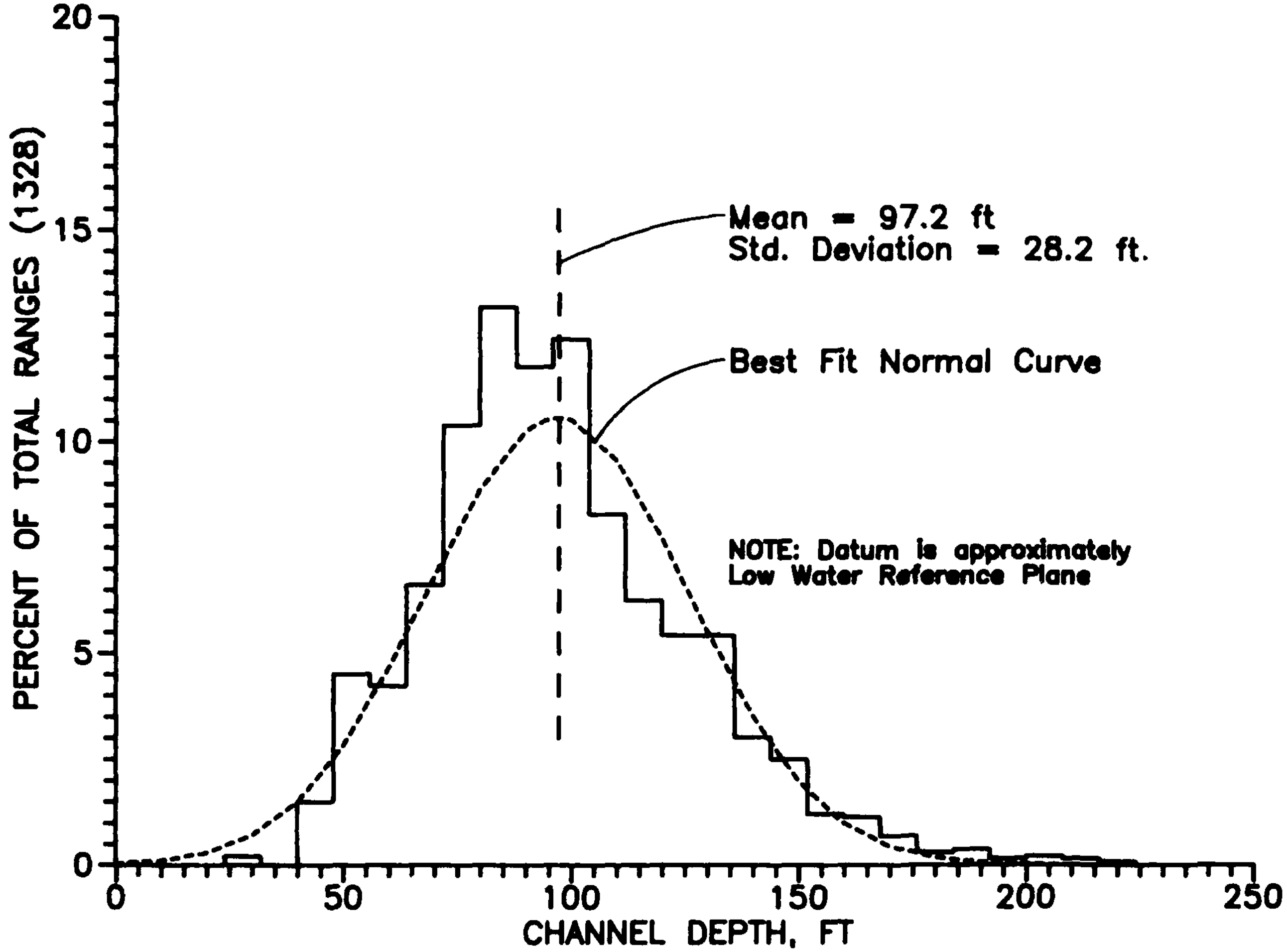


Figure 49. Frequency histogram, 1973-1975 channel depth, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

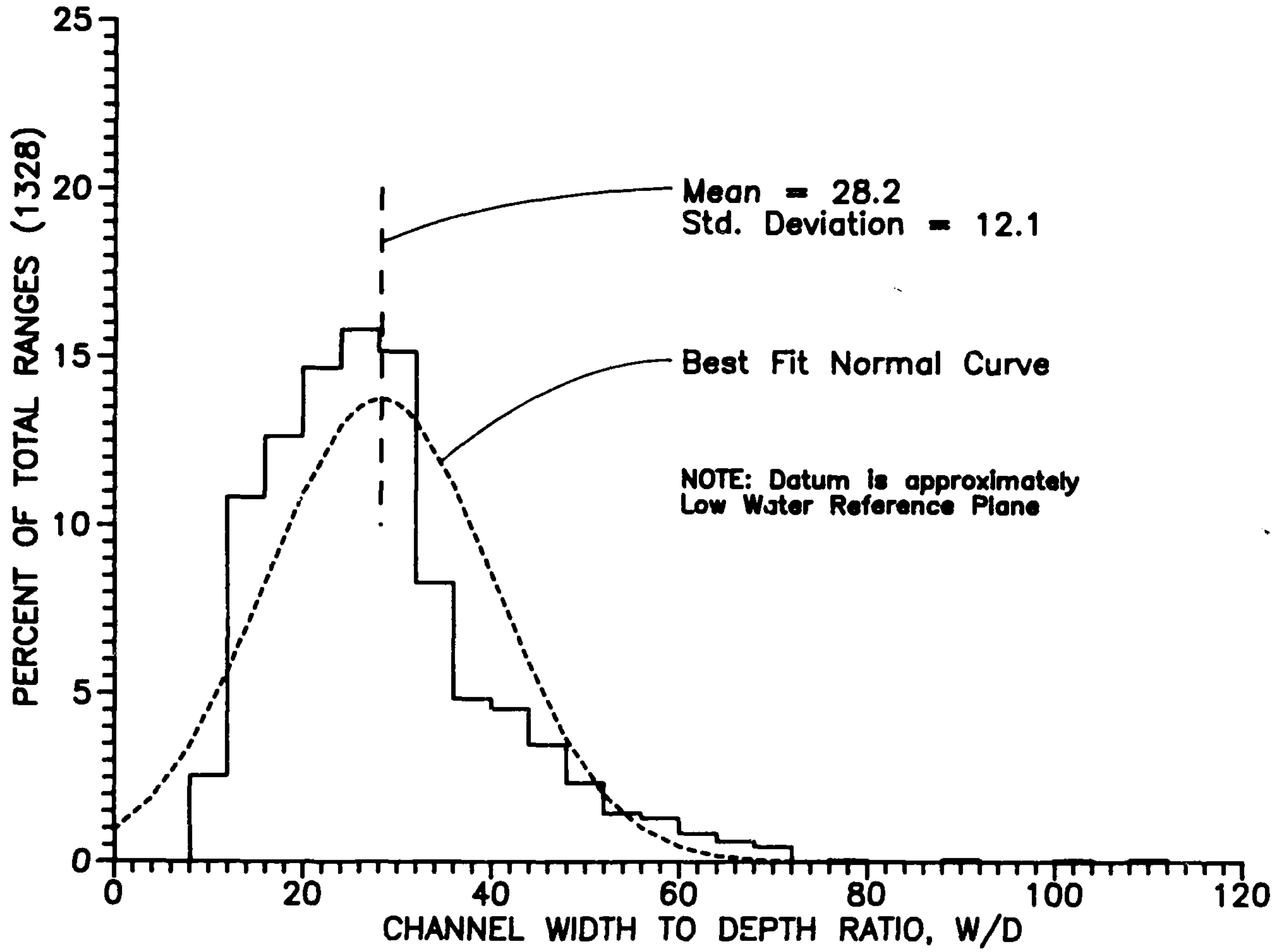


Figure 50. Frequency histogram, 1973-1975 channel W/D ratio, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

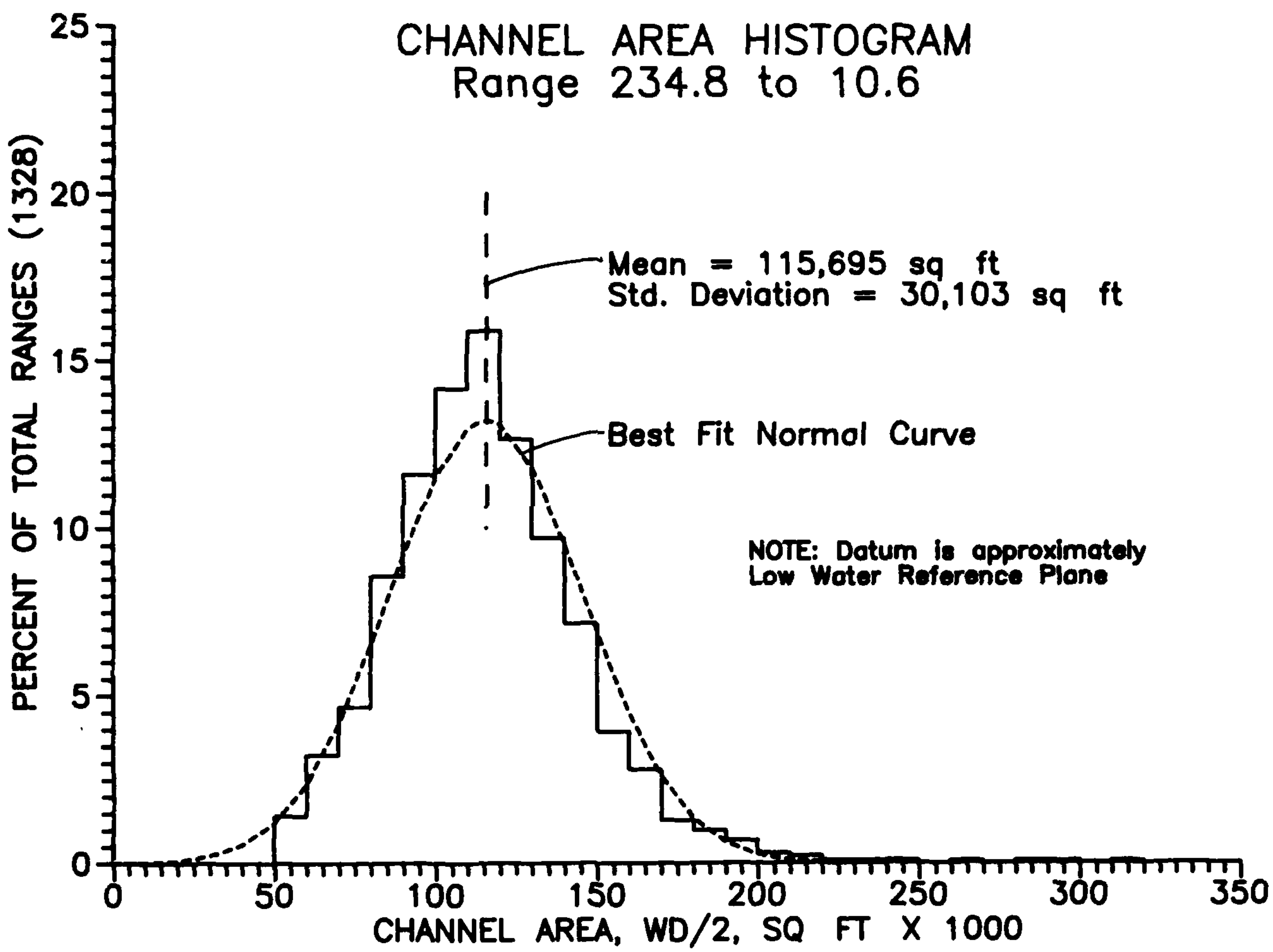


Figure 51. Frequency histogram, 1973-1975 channel triangular area, range 234.8 to 10.6, Mississippi River below Baton Rouge, LA

increase on the average in the downstream direction. Width-to-depth ratio (Figure 46) shows a distinct change in pattern near range R-110 which reflects the trends in width previously mentioned. Channel triangular area (Figure 47) exhibits a consistent tendency to increase in the downstream direction. The histograms reveal that width (Figure 48) is almost perfectly normally distributed (random variable), while area (Figure 51) is relatively normally distributed and depth exhibits the least normal trend of the three parameters. Width-to-depth ratio (Figure 50) is clearly skewed in its distribution.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

45. The following conclusions are drawn from the new work presented herein:

a. The Celotex batture and levee failure was the result of a flow slide in substratum sands triggered in the scour trench near Greenville Bend revetment range U-19. This bank reach had been classified as susceptible to flow failure.

b. The bank lines of record along the Greenville Bend revetment reach inclusive of the Celotex failure site indicate a regular history of failures including a past failure specifically at the Celotex site.

c. The "permanent" scour pool in Greenville Bend upstream of the Celotex failure site is migrating in a downstream and southeasterly direction and in the future will subject the flow slide susceptible right bank from revetment range U-30 to U-15 to increased attack and, consequently, cause an increased risk of additional flow slides.

d. The reason that the Celotex failure occurred during low water is not understood. Scour pool behavior over the seasons of the water year is not understood with sufficient clarity.

e. Empirical data from past Potamology Investigations, that of the flow slides below Baton Rouge in 1973, and that of the Celotex flow failure lend credence to the concept of the runout angle α as a typical trait of Mississippi Riverbank flow slides. Furthermore, that data imply that angle to be approximately 10 deg projected from a point tangent to the base of the scour pool/trench up through substratum sands to the base of the overburden stratum. Therefore, the potential loss of batture due to a flow slide can be estimated using the runout angle concept. Additional studies of future flow slides and of a theoretical nature are required to verify these observations.

f. The NOD has developed and is using a monitoring system based on observed scour and the 10-deg runout angle concept to permit assessment of levee stability site by site. This represents the first rational method for weighing flow slide threat to the levee. The extensive data base supporting that system contains information gaps which must be filled on a priority basis.

g. The historical data showing movement of the river channel over the last 90 years indicate the range in severity of bank erosion and the specific reaches suffering that range in attack.

h. Riverbank reaches classified as susceptible to flow failure and falling in any of the attack categories of severe, moderate, or minor as defined in this report should be considered at highest risk. These reaches should receive priority in the monitoring

data acquisition. Susceptible reaches not falling in these categories should be monitored until sufficient evidence warrants their removal from the system. Trends in scour pool migration must be included in these considerations. This dictates that trends in migration of any pertinent scour pools must be determined if unknown.

i. Historical data as to which bank soil profiles the river has most often successfully eroded coupled with the Marchand levee failure experience warn that deep sands underlying thick overburden strata will lead to upper bank instability, particularly in reaches of severe to moderate attack. It is thought probable that the failure mechanism in the sands is the same retrogressive one as for classical Mississippi River bank flow slides.

j. Historical trends in changes of river channel dimensions imply that average current velocities from Baton Rouge to Bonnet Carre Spillway are on the increase. If true, this portends an increase in bank stability problems along that reach with time.

k. Historical data show the river to be widening by eroding both banks downstream of about Bonnet Carre Spillway. This erosion mostly falls in the minor category with a few "hot spots" in the severe and moderate categories. Perhaps the implied reduction in average current velocities portends an improving situation except that flood periods should still produce problems in hot spots like the Nairn reach.

Recommendations

46. The following tasks and/or practices are recommended in continuance of the flow slide studies. It is not the intent of the author to infringe on the area of expertise of the River Engineering Branch. Those LMVD entities are pursuing and considering valuable flow slide associated studies of their own choosing in light of past geotechnical findings. The recommendations provided below are considered important to the geotechnical aspects of the problem.

a. All future flow slides below Baton Rouge, whether in revetted or unrevetted bank or whether a threat to the levee or not, should be surveyed in detail under water and above water. Survey ranges should not be more than 100 ft apart. These data are important in confirming the 10-deg runout angle.

b. With respect to the NOD monitoring system, consideration should be given to the question of what frequency of site hydrographic surveys is most appropriate. Annual surveys may not be adequate to see serious developments pending a better understanding of scour pool behavior through the water seasons.

c. The theoretical studies of the failure mechanism and runout angle currently in progress should be completed. It is desirable to draw empirical evidence and theory together to rest the case of existence of such a parameter and its most appropriate value.

d. The geological studies of the Marchand and Celotex bank reaches currently in progress should be completed. In addition, the direction of migration of all "permanent" scour pools below Baton Rouge should be determined from the historical data available.

e. A comprehensive study of old bank line data should be initiated to document the history of locations/trends of past bank failures below Baton Rouge. There is reason to believe that these data will yield strong evidence as to specifically where future failures may occur because those locations appear to be tied to persistent bank losses indicated by historical bank line comparisons.

f. There is a great need to develop a better understanding of exactly what goes on in scour pools through the stages of the river representing extremes of record. Behavior through typical annual stage variations is important but probably not sufficient. This is the only way the author can see the means to study development of oversteepening of slopes in the sands and subsequent flow. This can only be achieved by detailed, accurate surveys of selected pools in sands at intervals fitted to river stage. Available computer software will permit three-dimensional views, rotation of view, sectioning at will, and time-frame "movies" of changes. The larger the number of "permanent" and migrating scour pools in sand which are studied, the greater the probability of observing the pertinent mechanisms in a shorter period of time.

REFERENCES

Clough, G. W. 1966. "Ground Water Level in Silty and Sandy Mississippi River Upper Banks," Mississippi River Commission, Corps of Engineers, Vicksburg, MS (Mr. F. J. Weaver of LMVD was a principal assistant in this study).

Gann, A. R. 1981. "Verification of Empirical Method for Determining River-bank Stability, Report 12-24, 1974 Through 1977 Data," Miscellaneous Paper S-78-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Hvorslev, M. J. 1956. "A Review of the Soils Studies," Potamology Investigations Report No. 12-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Padfield, C. J. 1978. "The Stability of River Banks and Flood Embankments," Final Technical Report, US Army European Research Office, London England.

Torrey, V. H., Dunbar, J. B., and Peterson, R. W. "Retrogressive Failures in Sand Deposits of the Mississippi River, Report 1, Field Investigations, Laboratory Studies and Analysis of the Hypothesized Failure Mechanism" (In preparation), US Army Engineer Waterways Experiment Station, Vicksburg, MS.

US Army Engineer Waterways Experiment Station. 1950. "Piezometer Observations at Reid Bedford Bend and Indicated Seepage Forces," Potamology Investigations Report No. 5-4, Vicksburg, MS.

APPENDIX A

MISSISSIPPI RIVER BELOW BATON ROUGE, LA, COMPARISON OF BANK LINES BETWEEN 1879-1894 AND 1973-1975 HYDROGRAPHIC SURVEYS

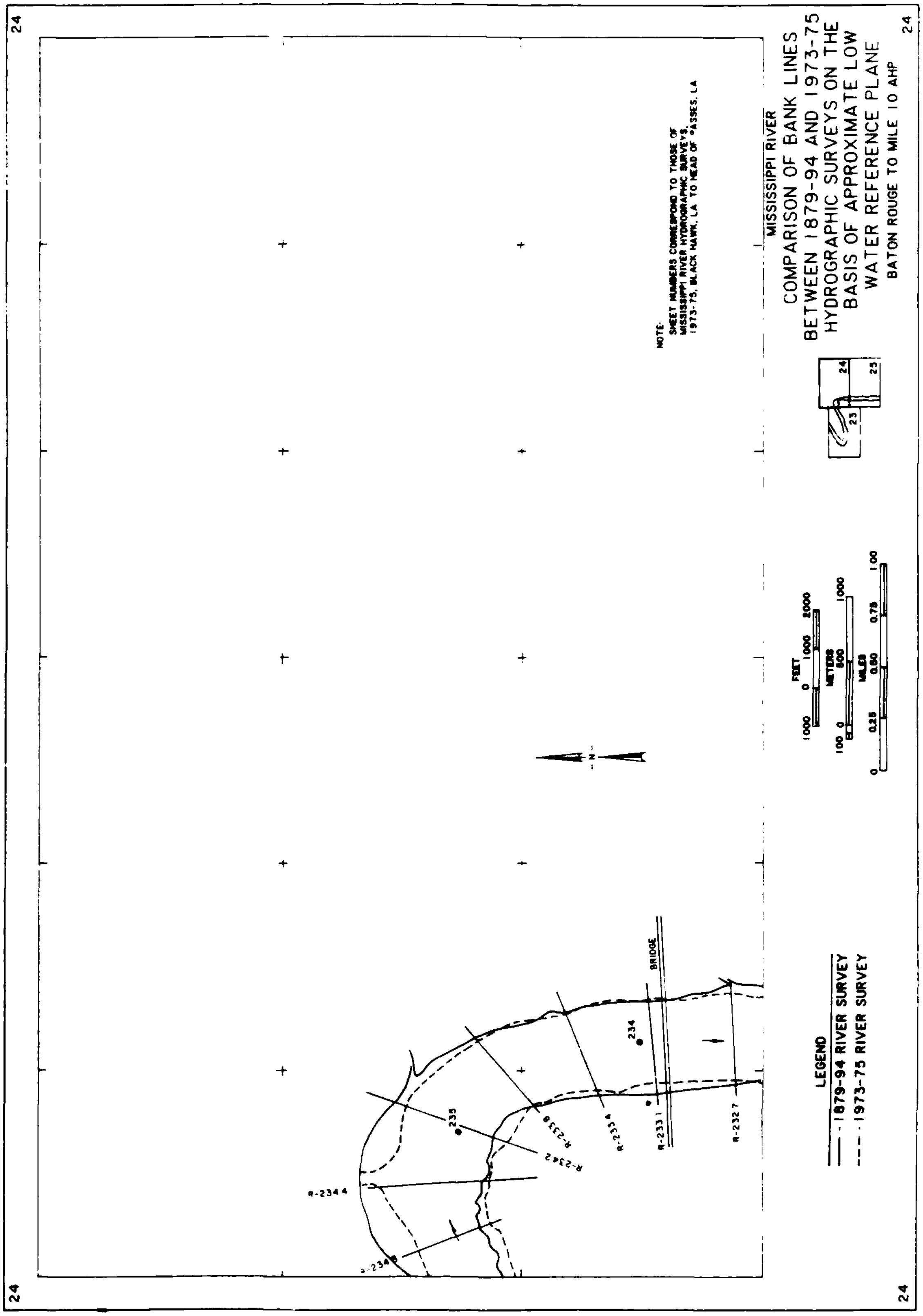

24
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
23
24
25
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
N
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
BRIDGE
234
235
R-2327
R-2331
R-2334
R-2338
R-2342
R-2344
R-2348

PLATE A1

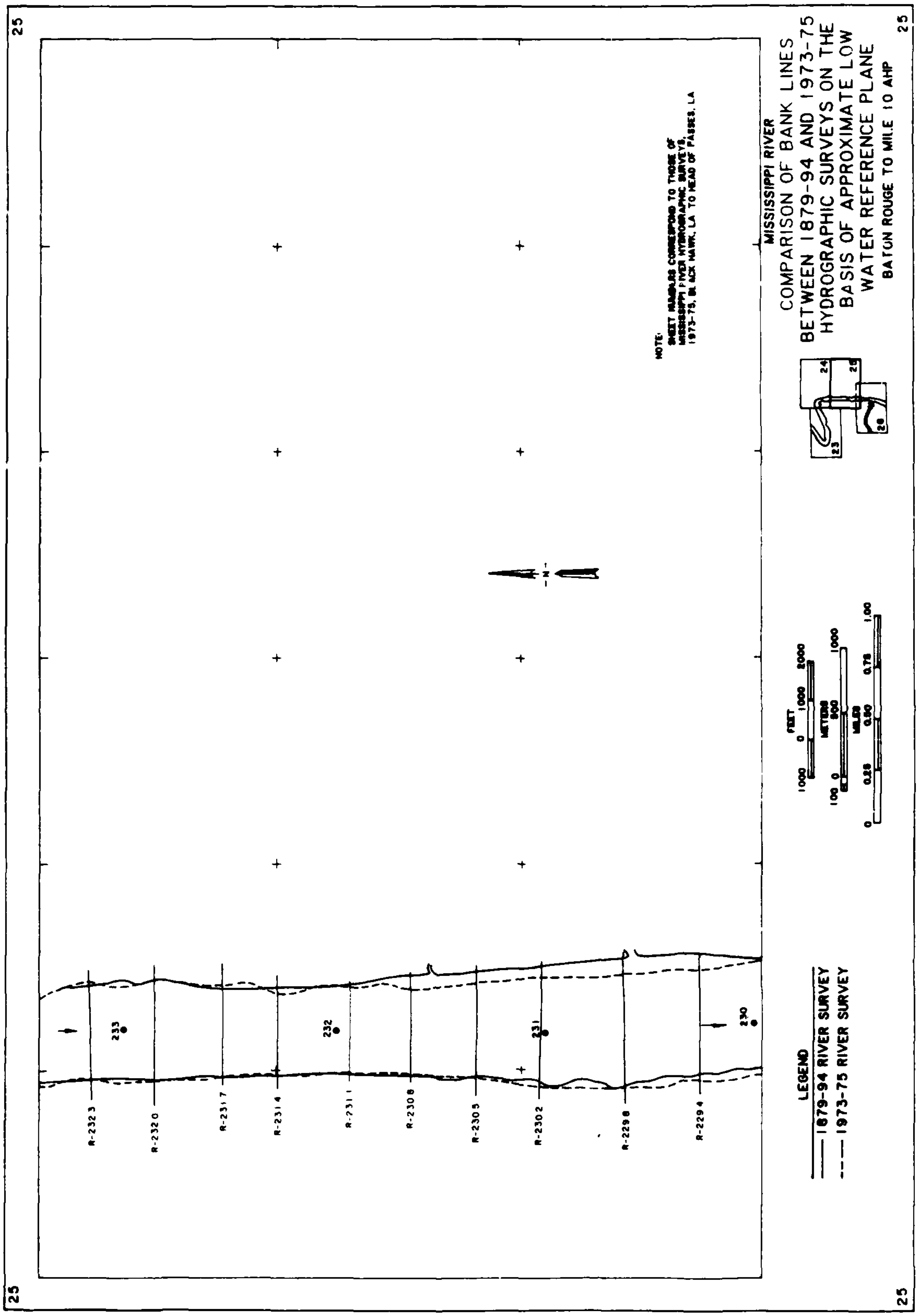
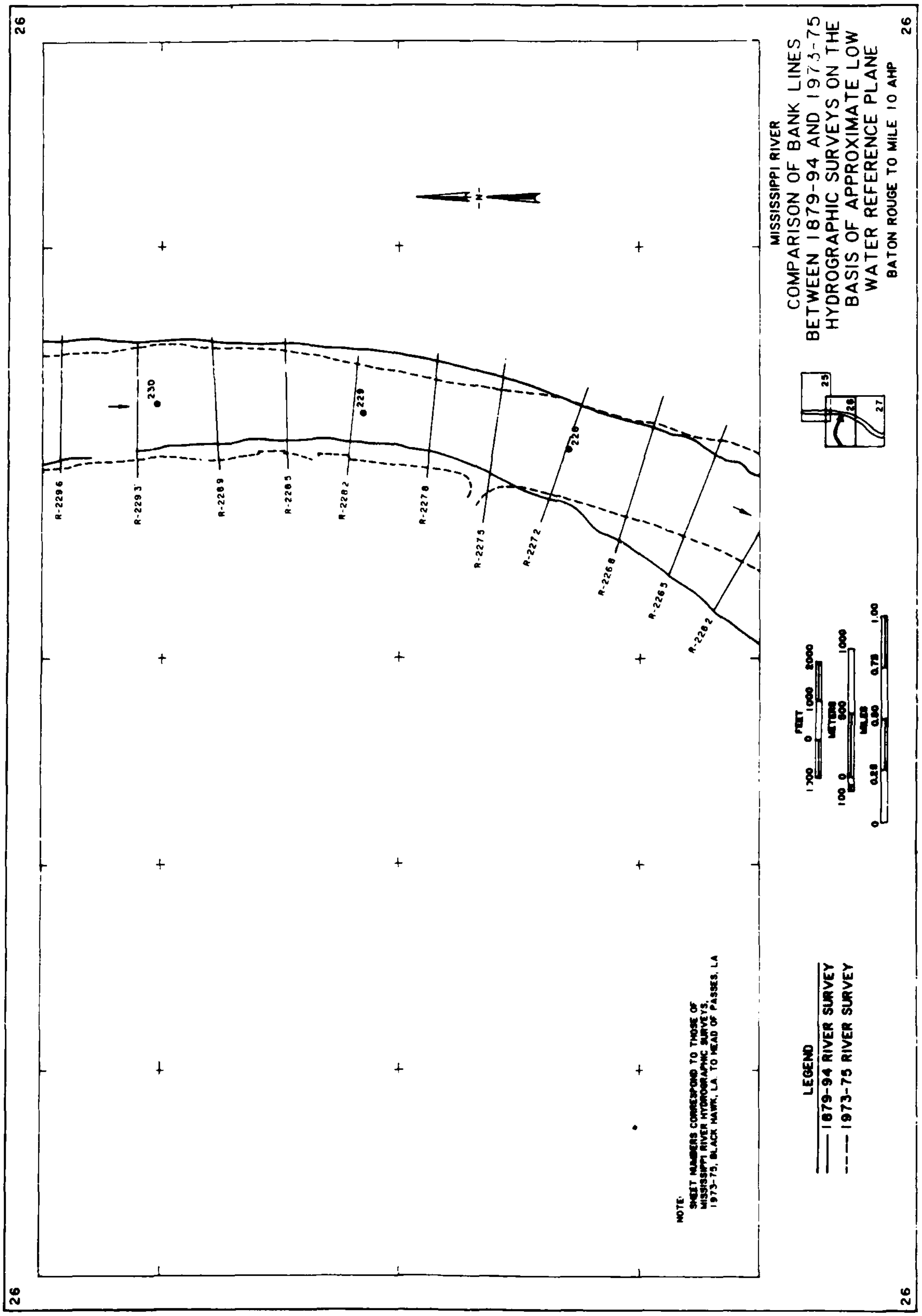

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES
25
R-2323
R-2320
R-2317
R-2314
R-2311
R-2308
R-2305
R-2302
R-2298
R-2294
233
232
231
230

PLATE A2



26
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
N
230
229
228
R-2296
R-2293
R-2289
R-2285
R-2282
R-2278
R-2275
R-2272
R-2268
R-2265
R-2262
25
26
27
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA

PLATE A3

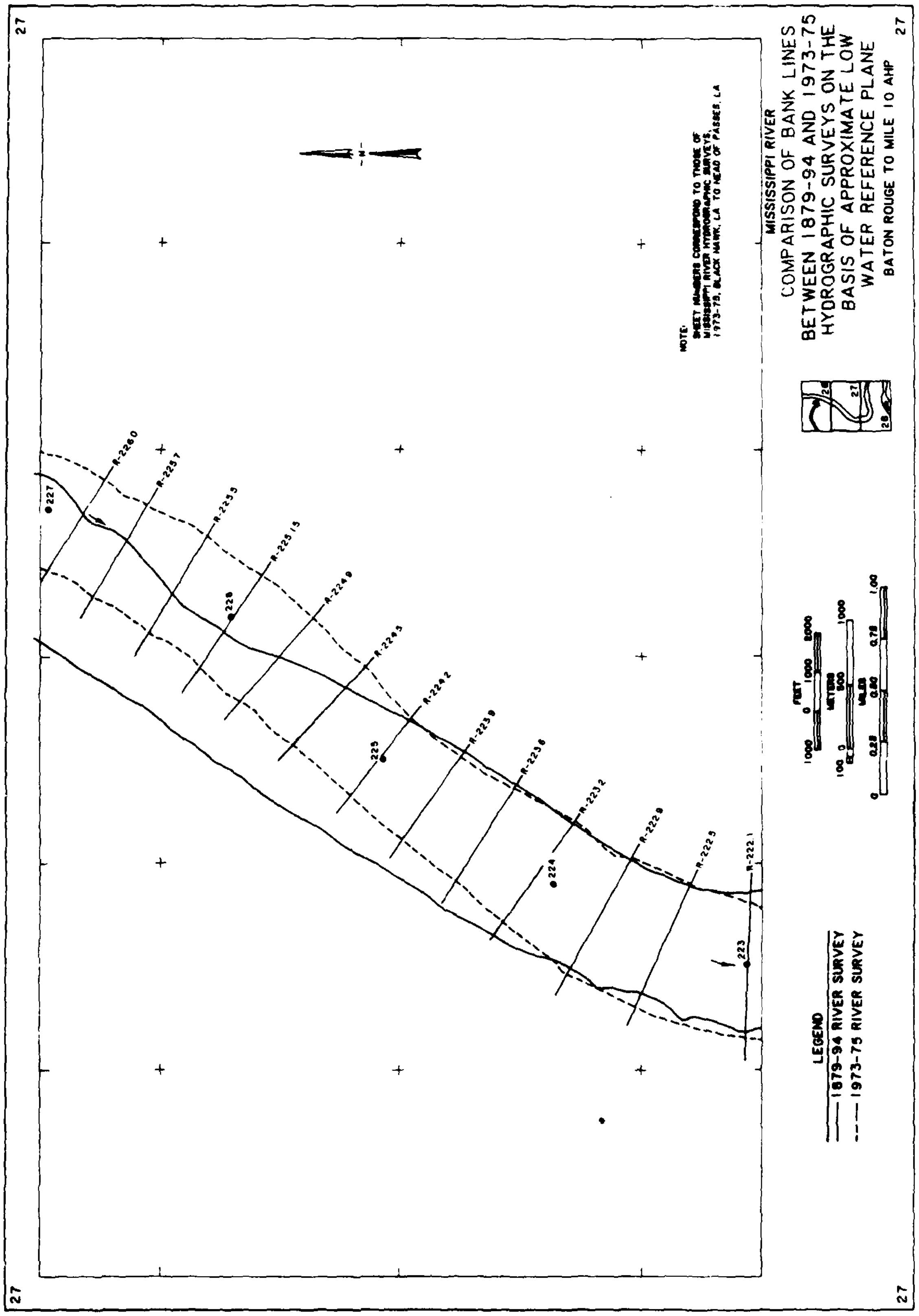

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
27

PLATE A4

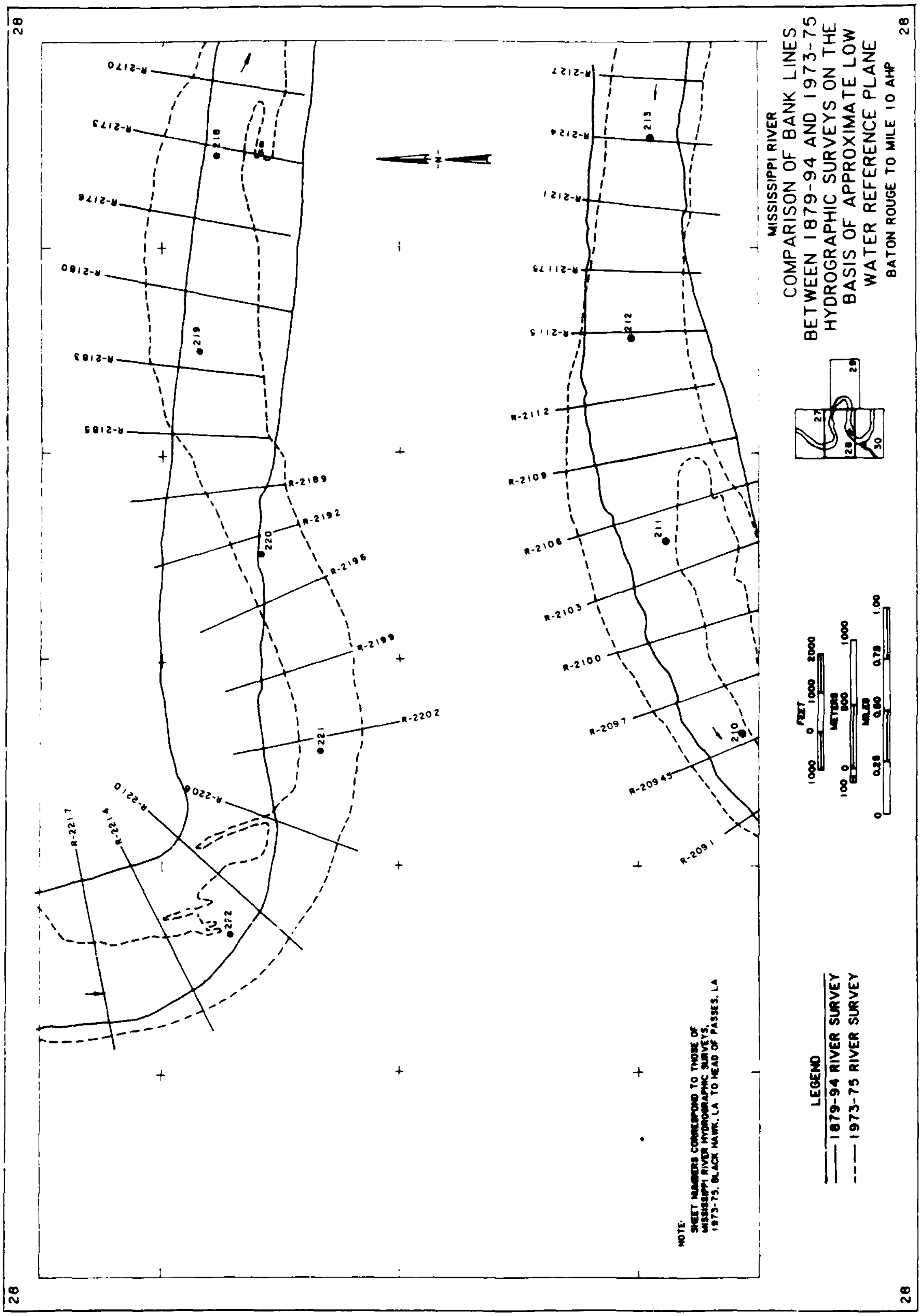

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
28
R-2170
R-2173
R-2176
R-2180
R-2183
R-2185
R-2189
R-2192
R-2196
R-2199
R-2202
R-2205
R-2210
R-2214
R-2217
R-2127
R-2124
R-2121
R-2118
R-2115
R-2112
R-2109
R-2106
R-2103
R-2100
R-2097
R-2094.5
R-2091
218
219
220
221
222
213
212
211
210

PLATE A5

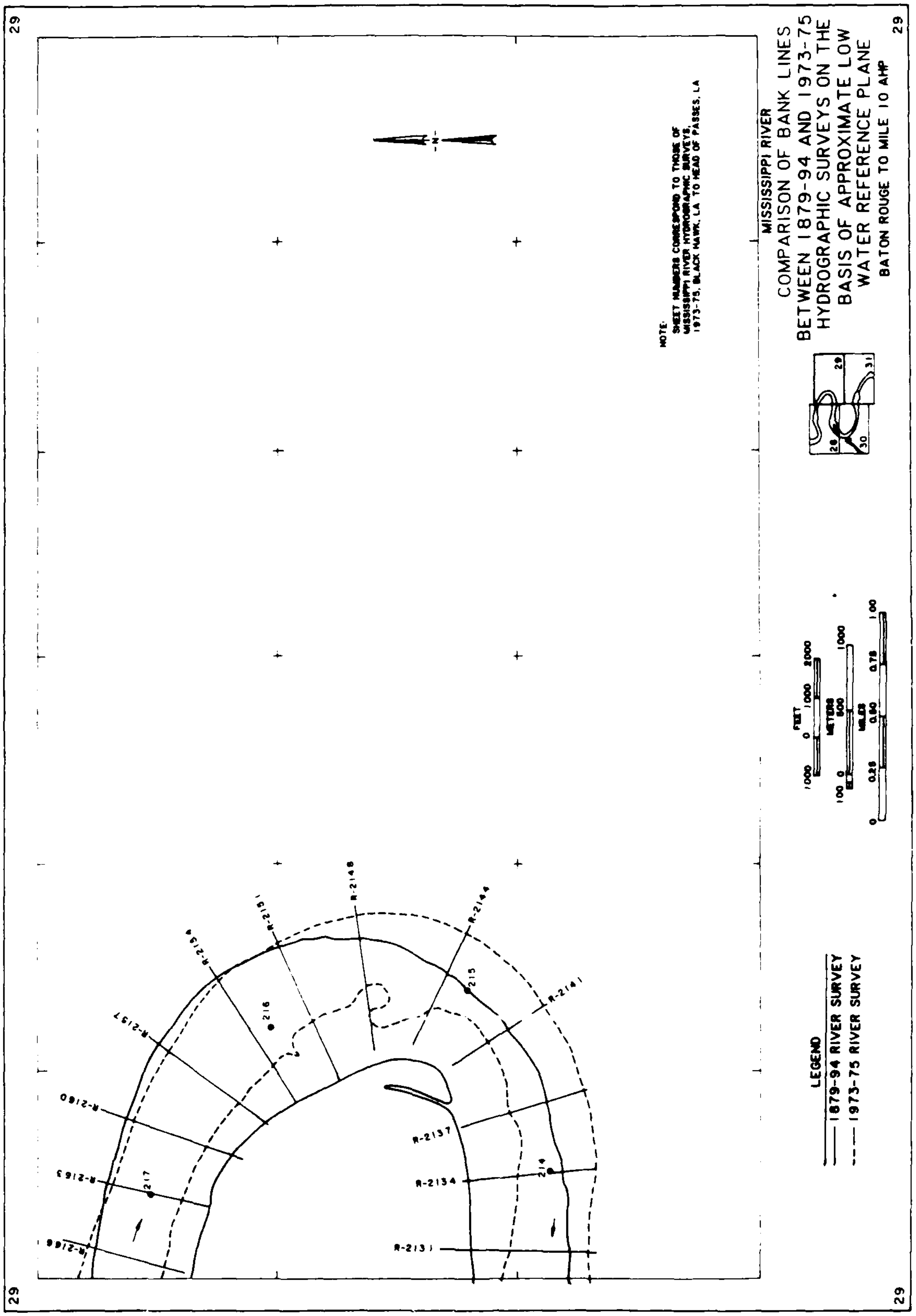
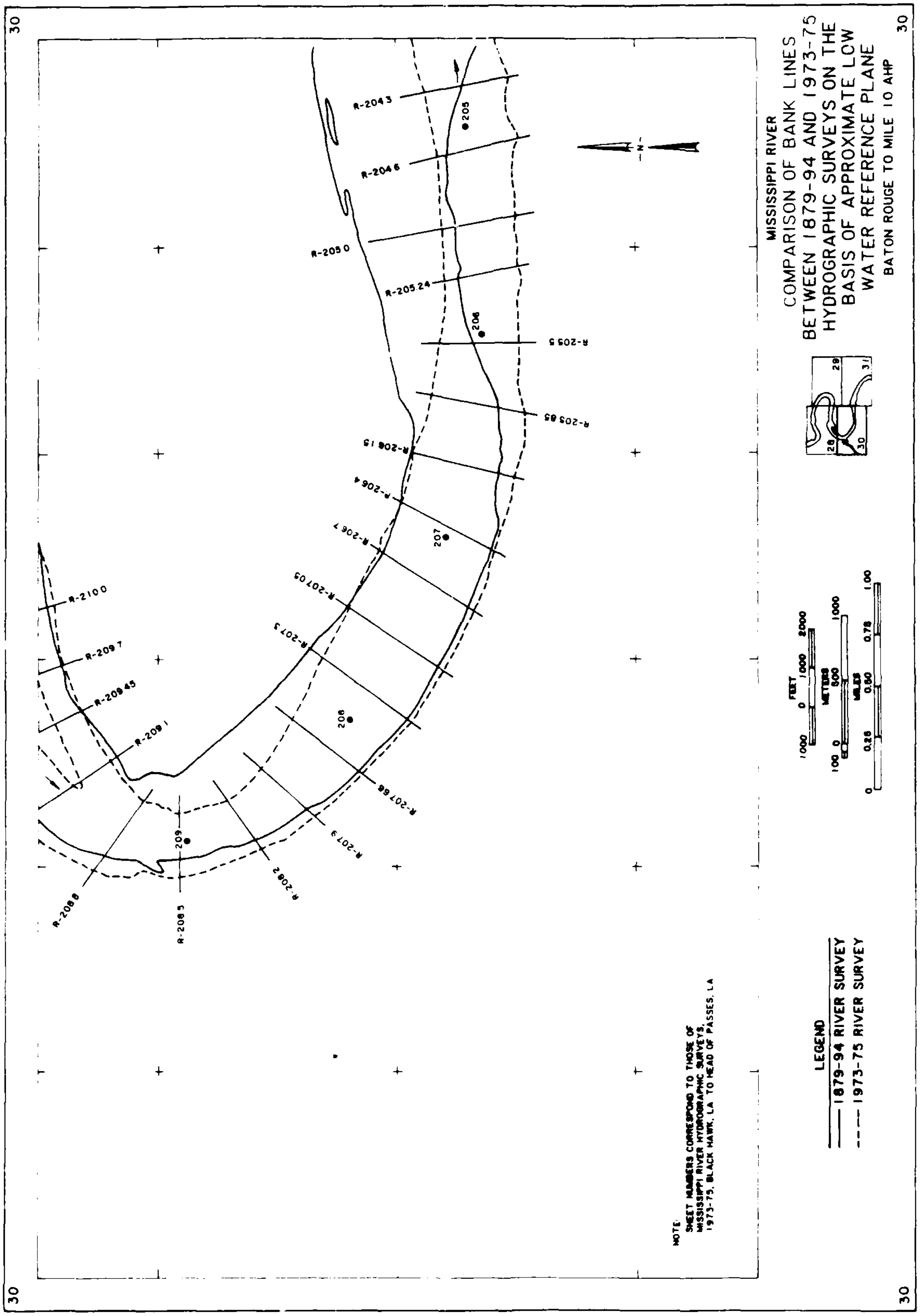

29
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
N
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
28
29
30
31
R-2131
R-2134
R-2137
R-2141
R-2144
R-2148
R-2151
R-2154
R-2157
R-2160
R-2163
R-2166
214
215
216
217

PLATE A6



MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES

PLATE A7

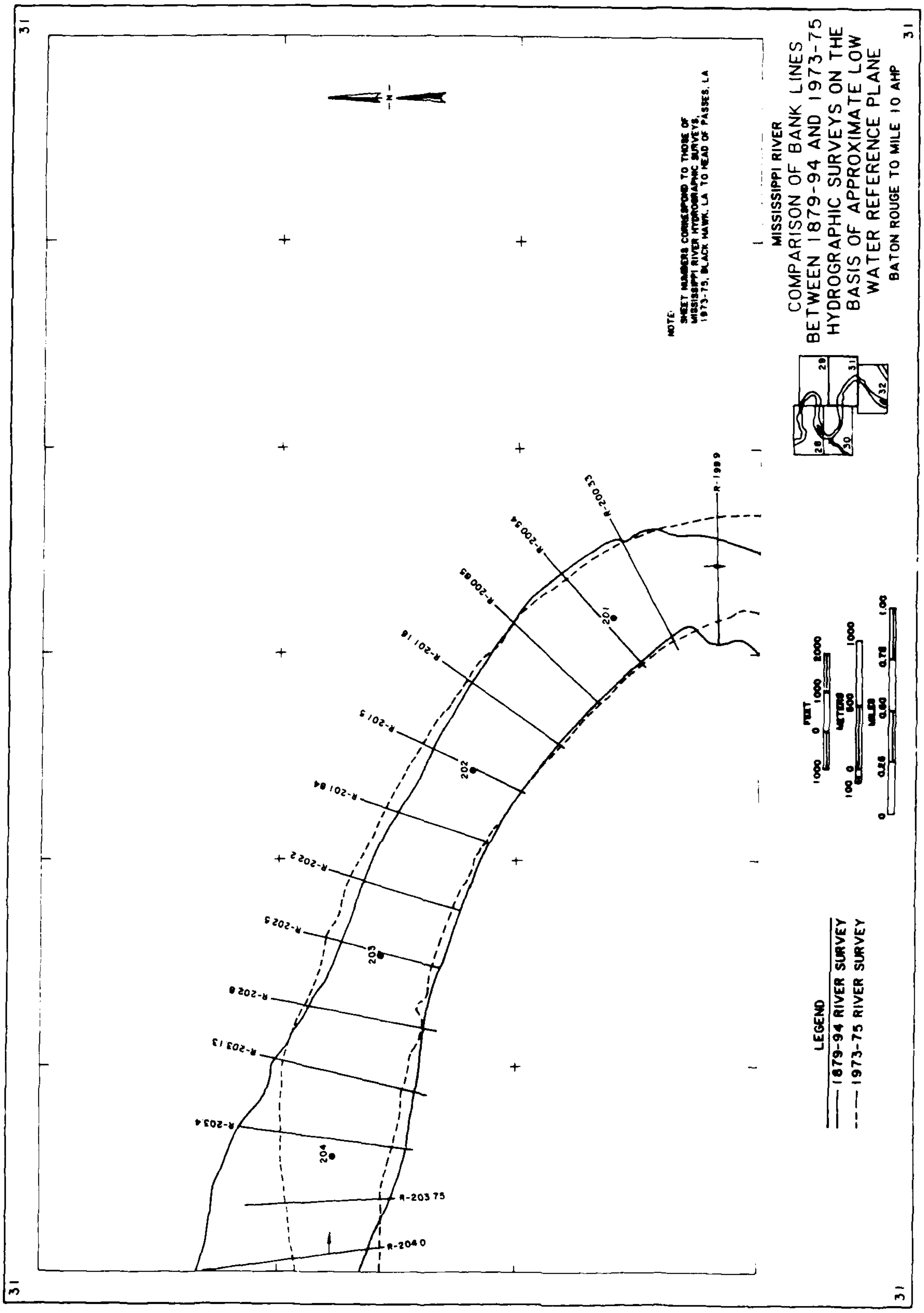

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES
N
31
R-199.9
R-200.33
R-200.54
R-200.85
R-201.16
R-201.5
R-201.84
R-202.2
R-202.5
R-202.8
R-203.13
R-203.4
R-203.75
R-204.0
201
202
203
204

PLATE A8

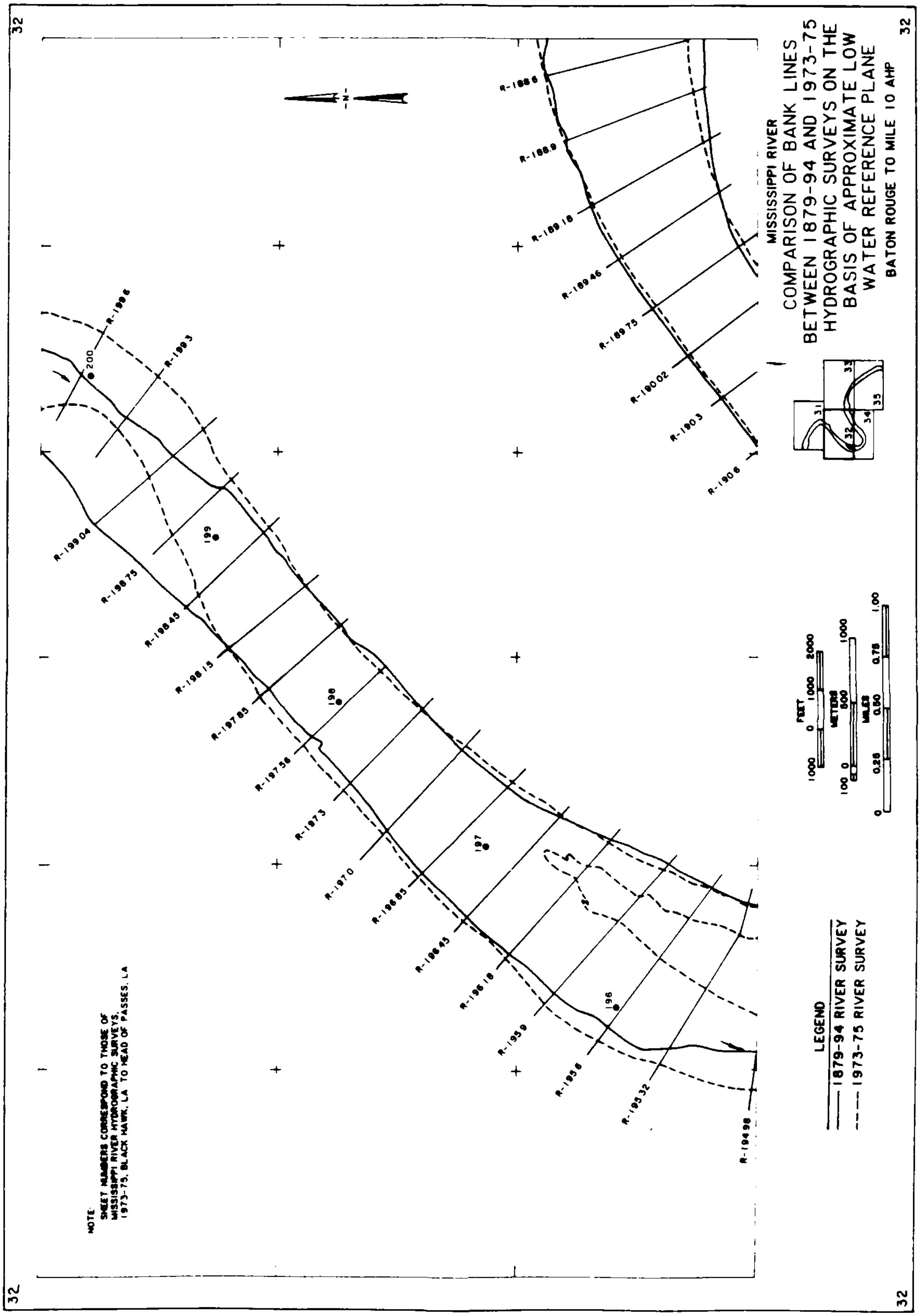

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
32

PLATE A9

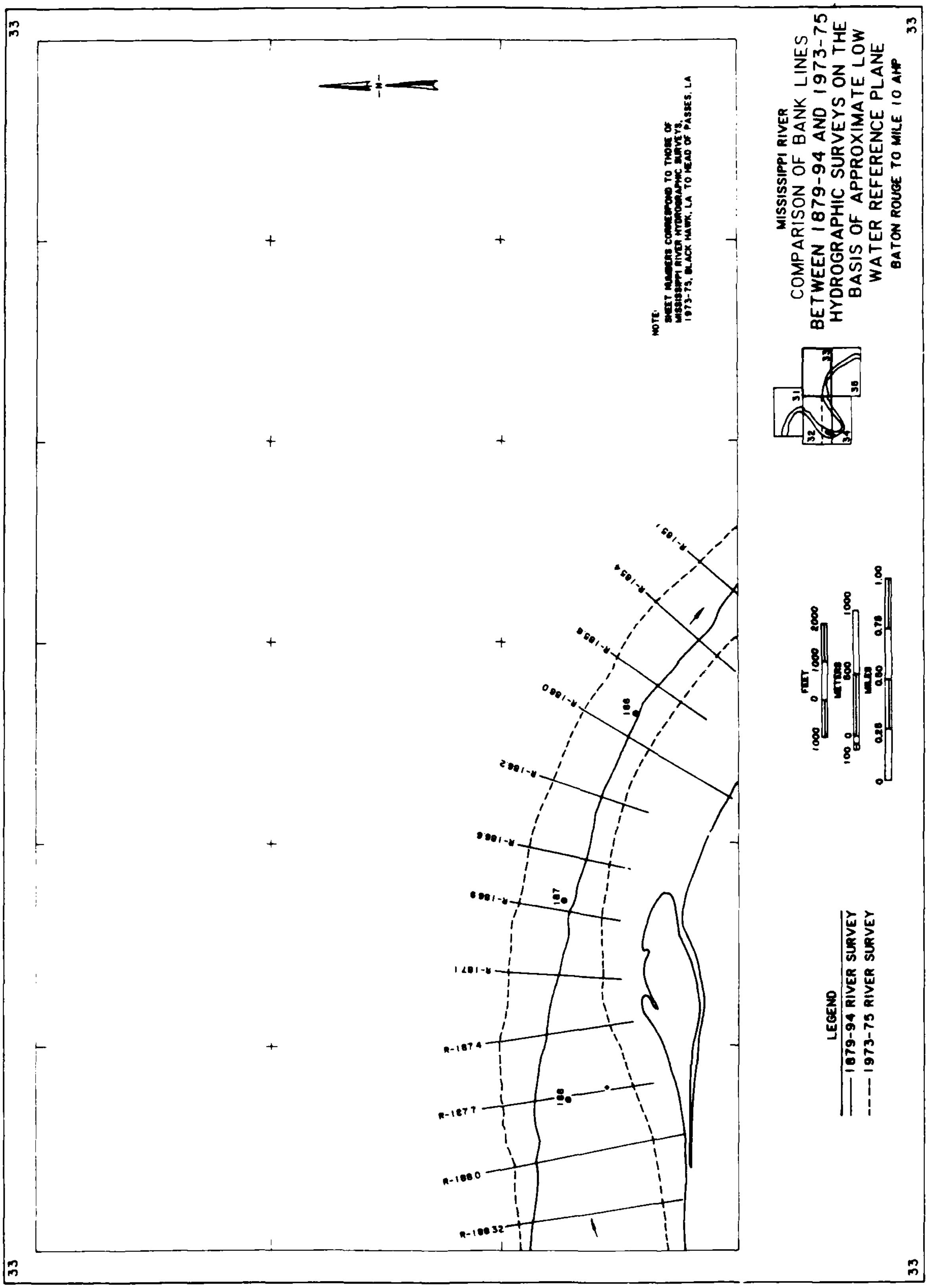

33
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES
186
187
188
R-1874
R-1877
R-1880

PLATE A10

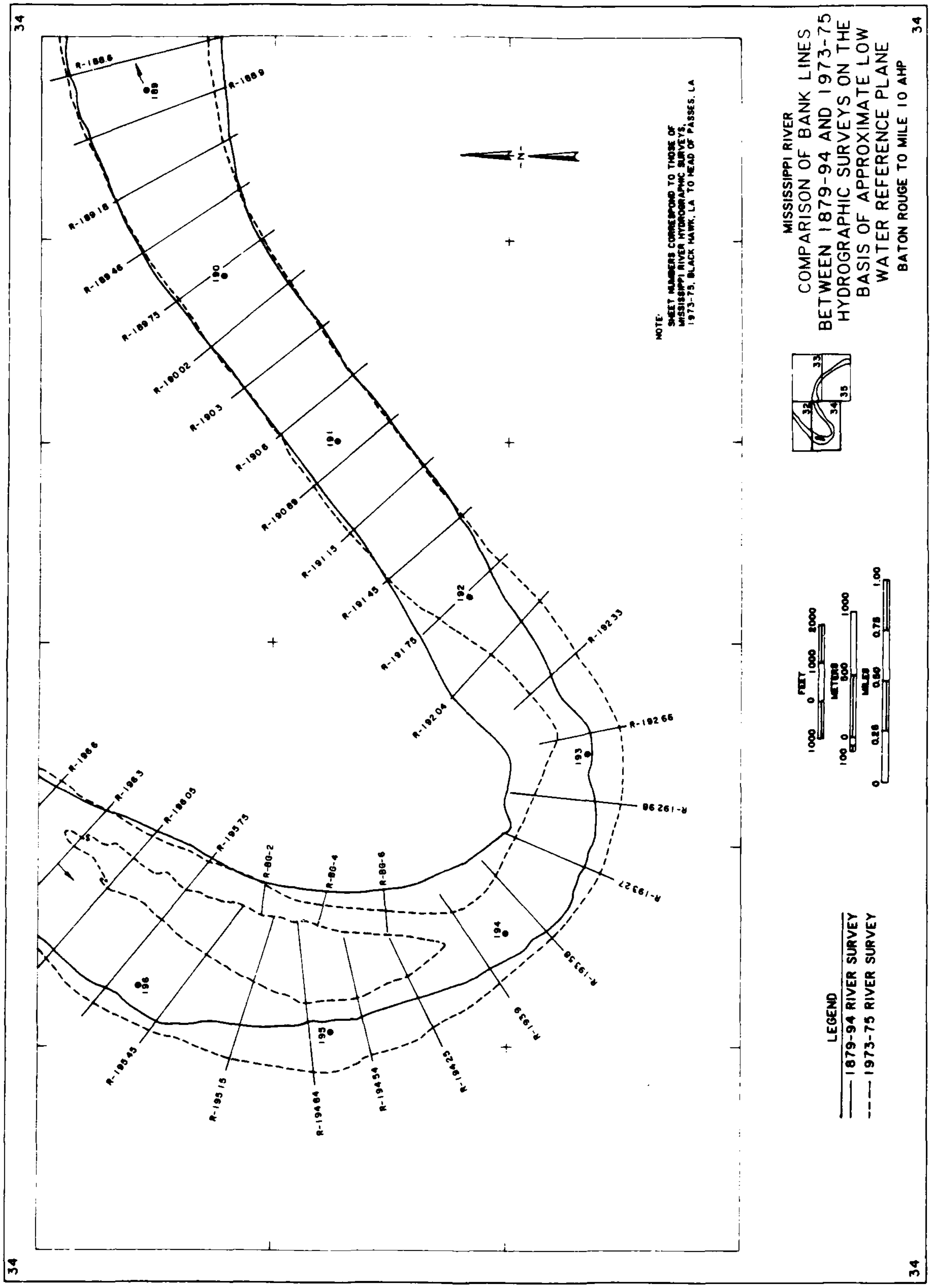

34
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES

PLATE A11

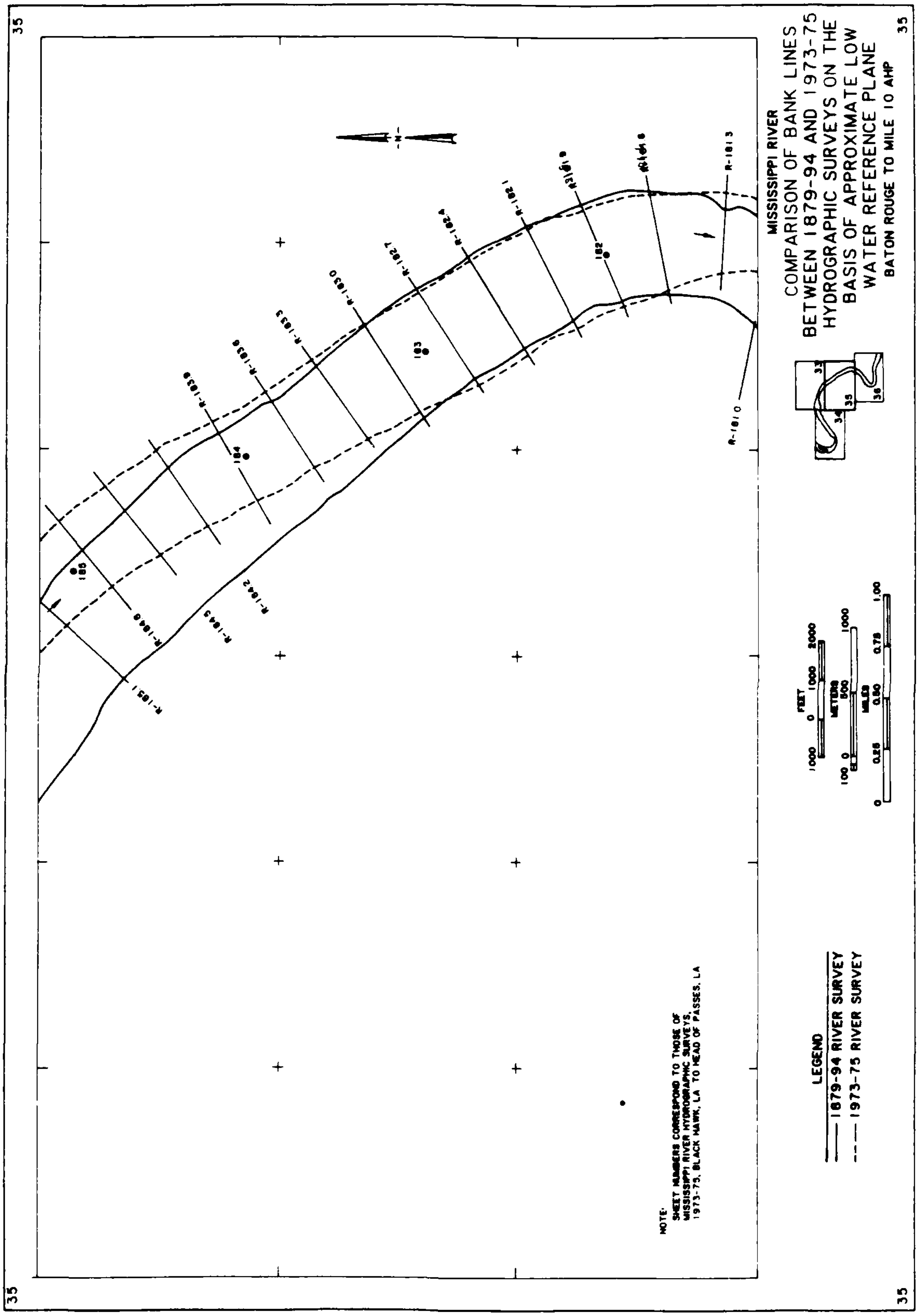

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
35

PLATE A12

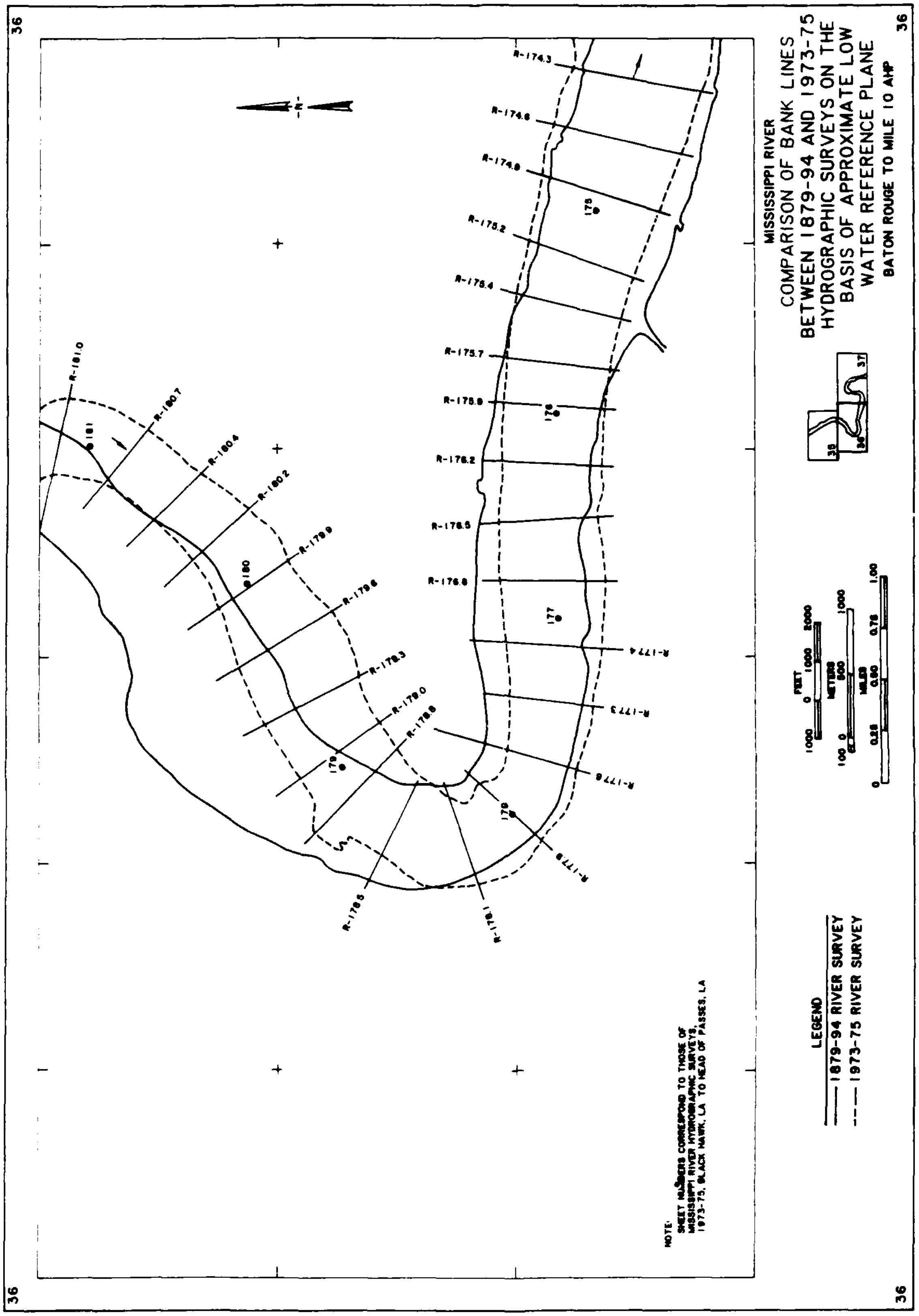

MISSISSIPPI RIVER
COMPARISON OF BANK LINES BETWEEN 1879-94 AND 1973-75 HYDROGRAPHIC SURVEYS ON THE BASIS OF APPROXIMATE LOW WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
36

PLATE A13

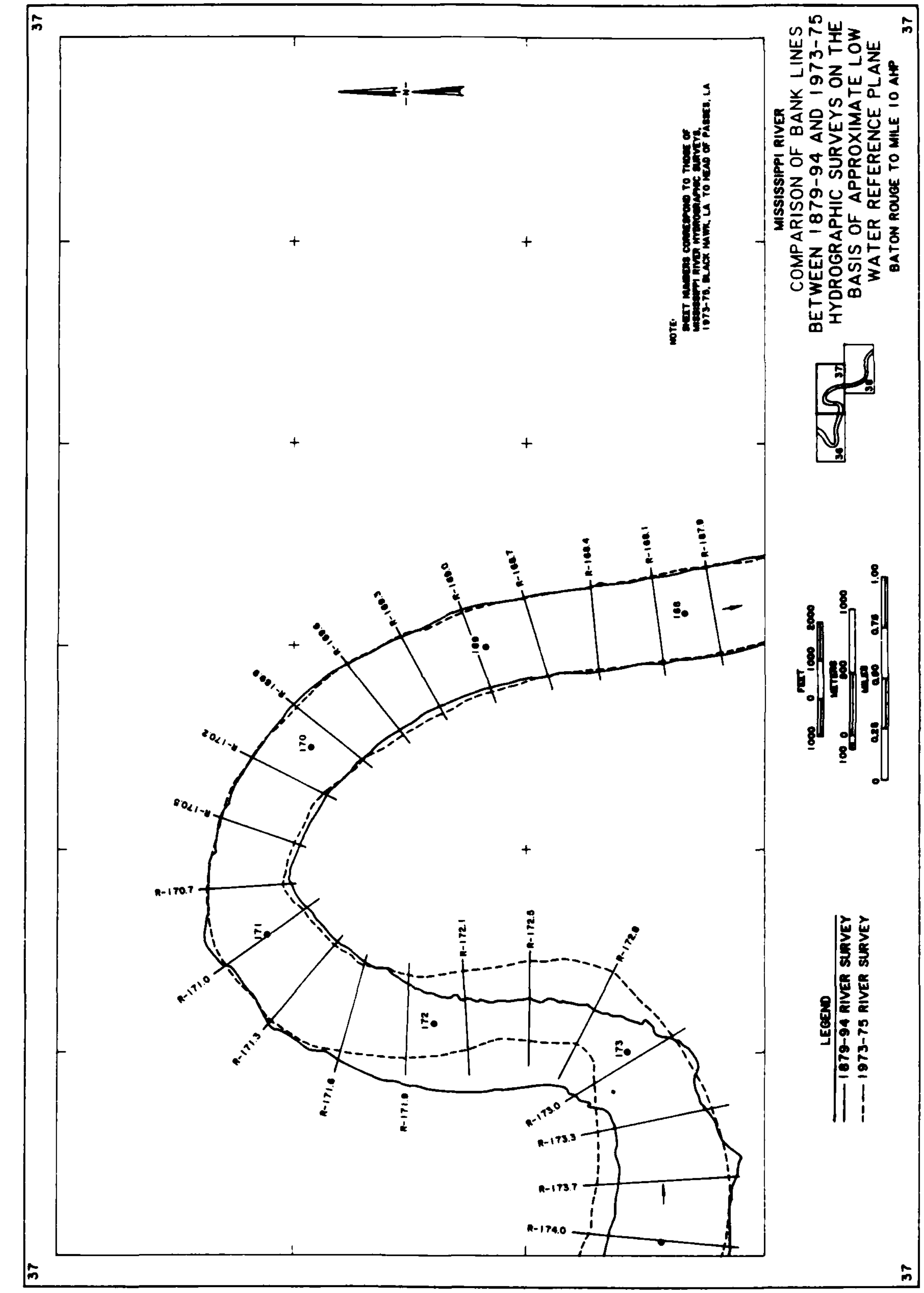
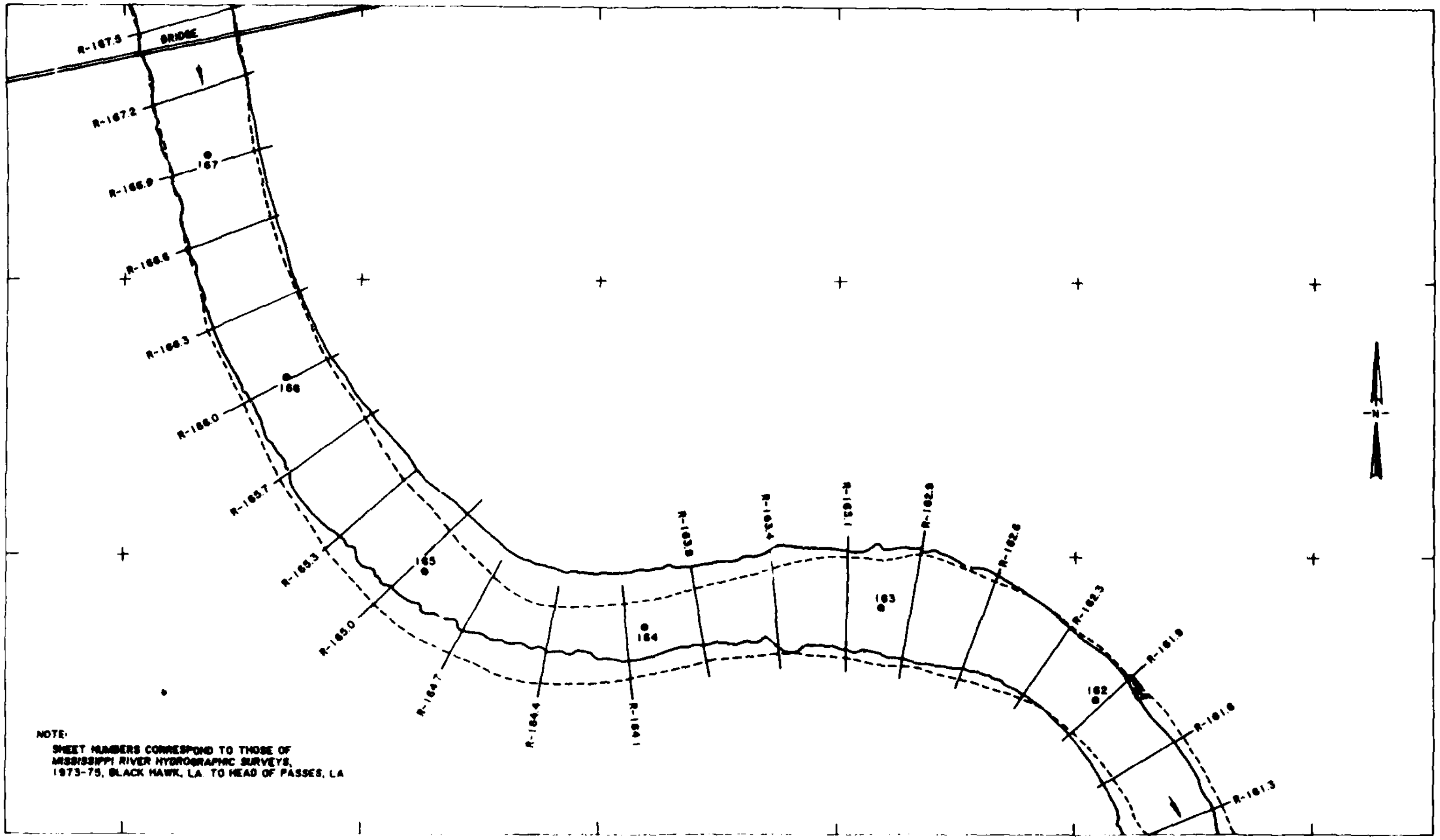

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
37

PLATE A14

38



NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA

LEGEND
—— 1879-94 RIVER SURVEY
- - - 1973-75 RIVER SURVEY

FEET 1000 0 1000 2000
METERS 100 0 500 1000
MILES 0 0.25 0.50 0.75 1.00

37 38 39

MISSISSIPPI RIVER
COMPARISON OF BANK LINES BETWEEN 1879-94 AND 1973-75 HYDROGRAPHIC SURVEYS ON THE BASIS OF APPROXIMATE LOW WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP

38

PLATE A15

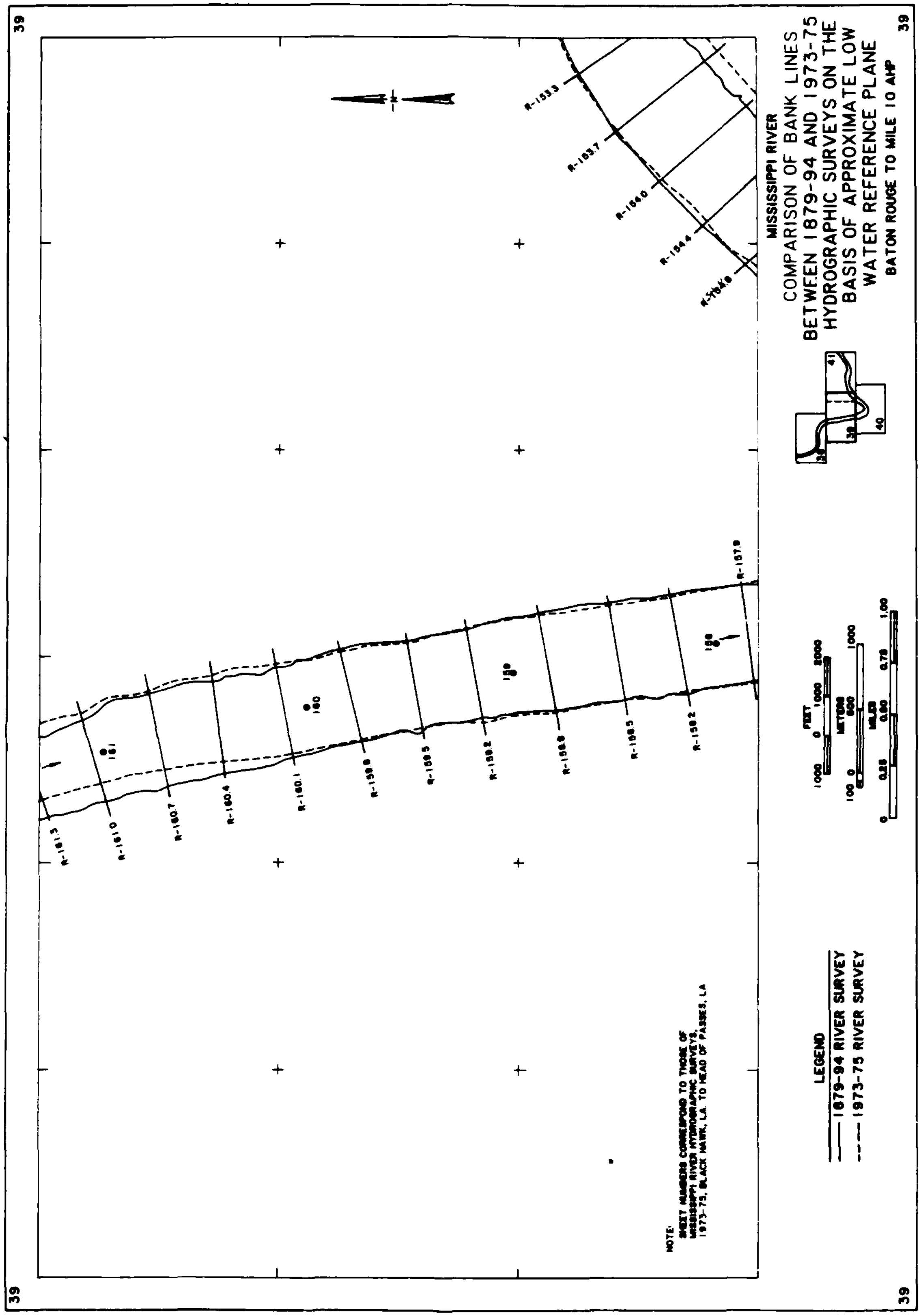

39
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.
FEET
METERS
MILES

PLATE A16

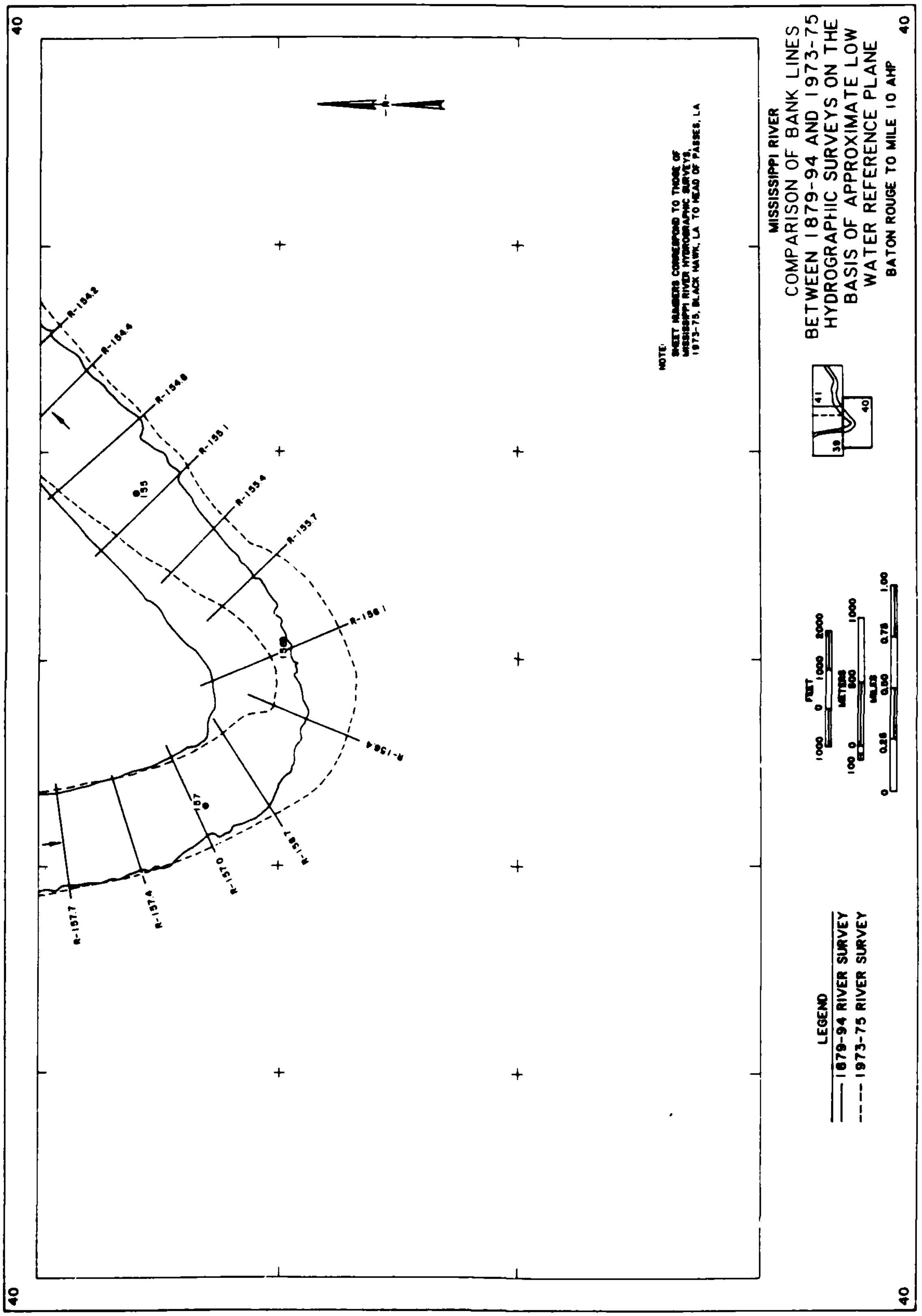

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES
R-154.2
R-154.4
R-154.8
R-155.1
R-155.4
R-155.7
R-156.1
R-156.4
R-156.7
R-157.0
R-157.4
R-157.7
155
156
157
40

PLATE A17

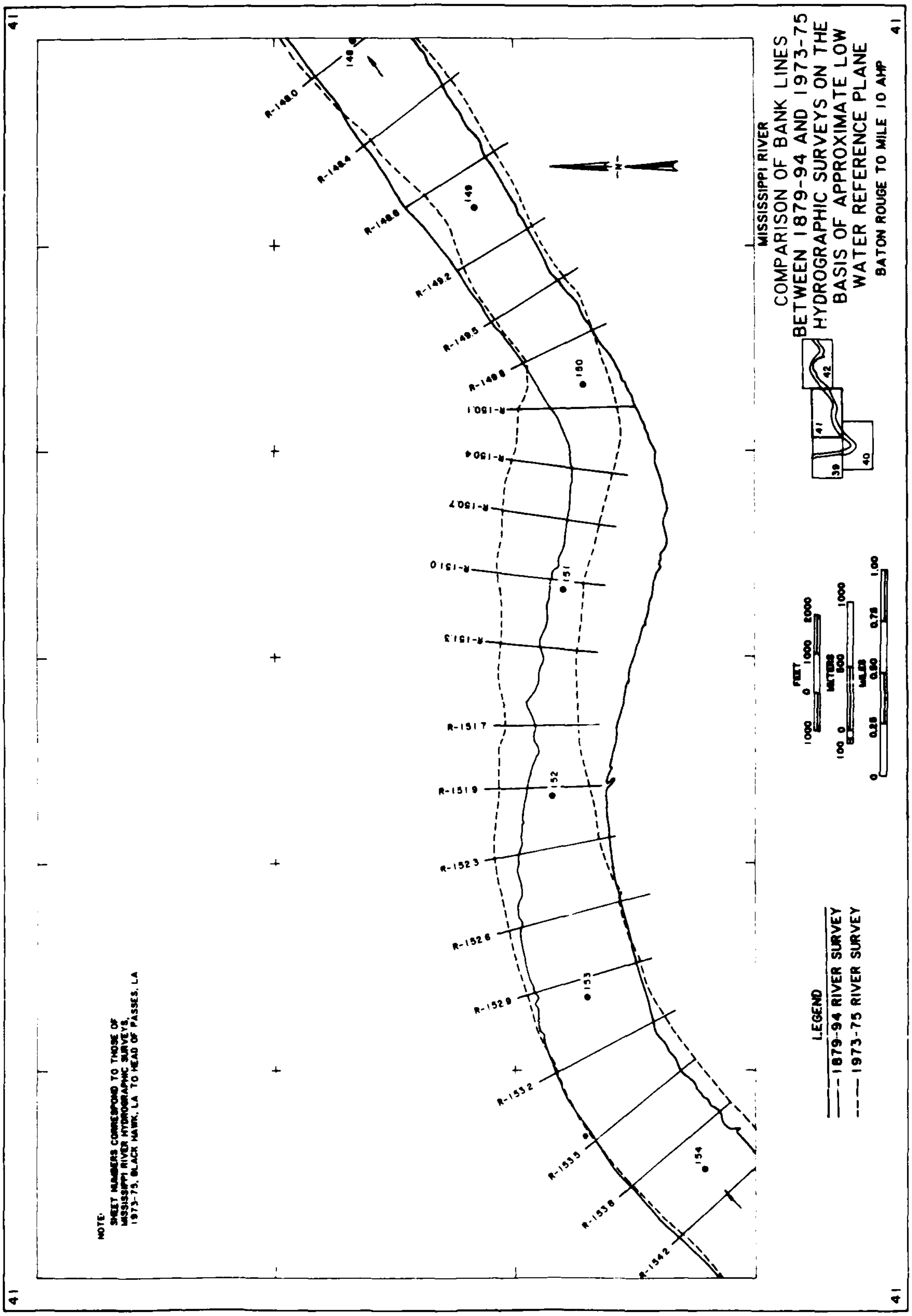
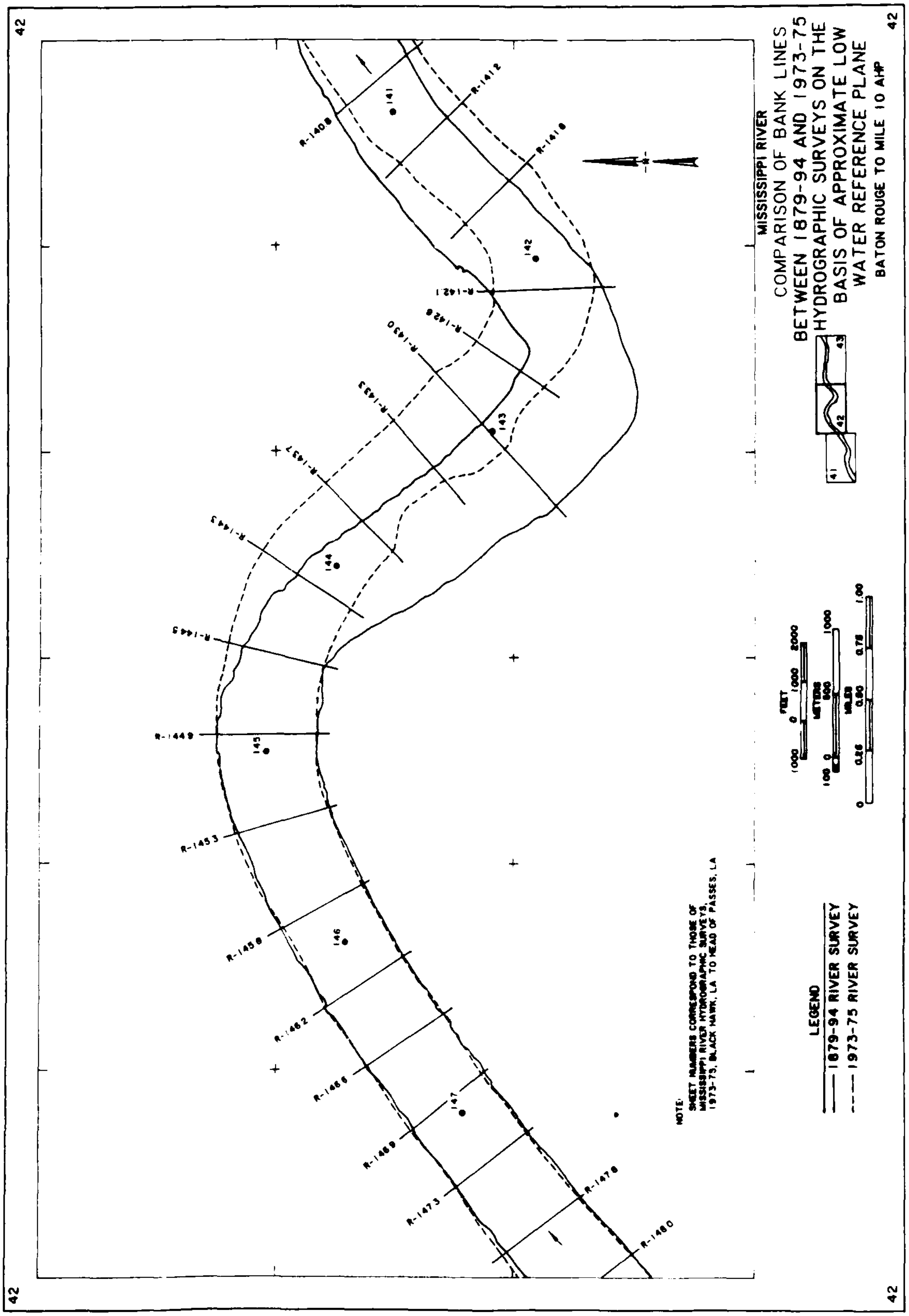

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
41

PLATE A18


MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
42
41
43
R-1408
R-1412
R-1416
R-1421
R-1426
R-1430
R-1433
R-1437
R-1443
R-1445
R-1449
R-1453
R-1458
R-1462
R-1466
R-1469
R-1473
R-1476
R-1480
141
142
143
144
145
146
147

PLAET A19

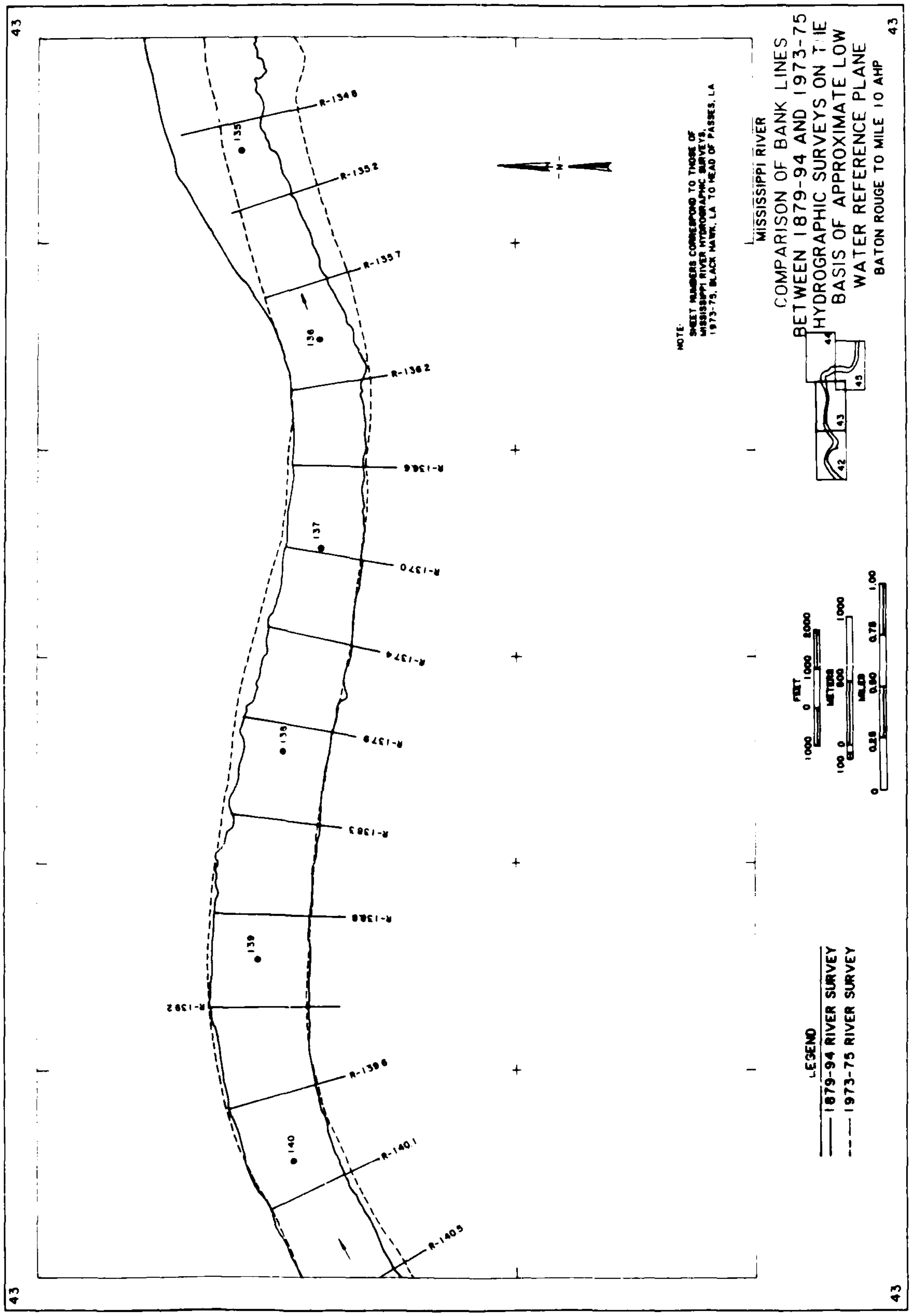

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES
43
42
44
45
135
136
137
138
139
140
R-1348
R-1352
R-1357
R-1362
R-1366
R-1370
R-1374
R-1379
R-1383
R-1388
R-1392
R-1396
R-1401
R-1405

PLATE A20

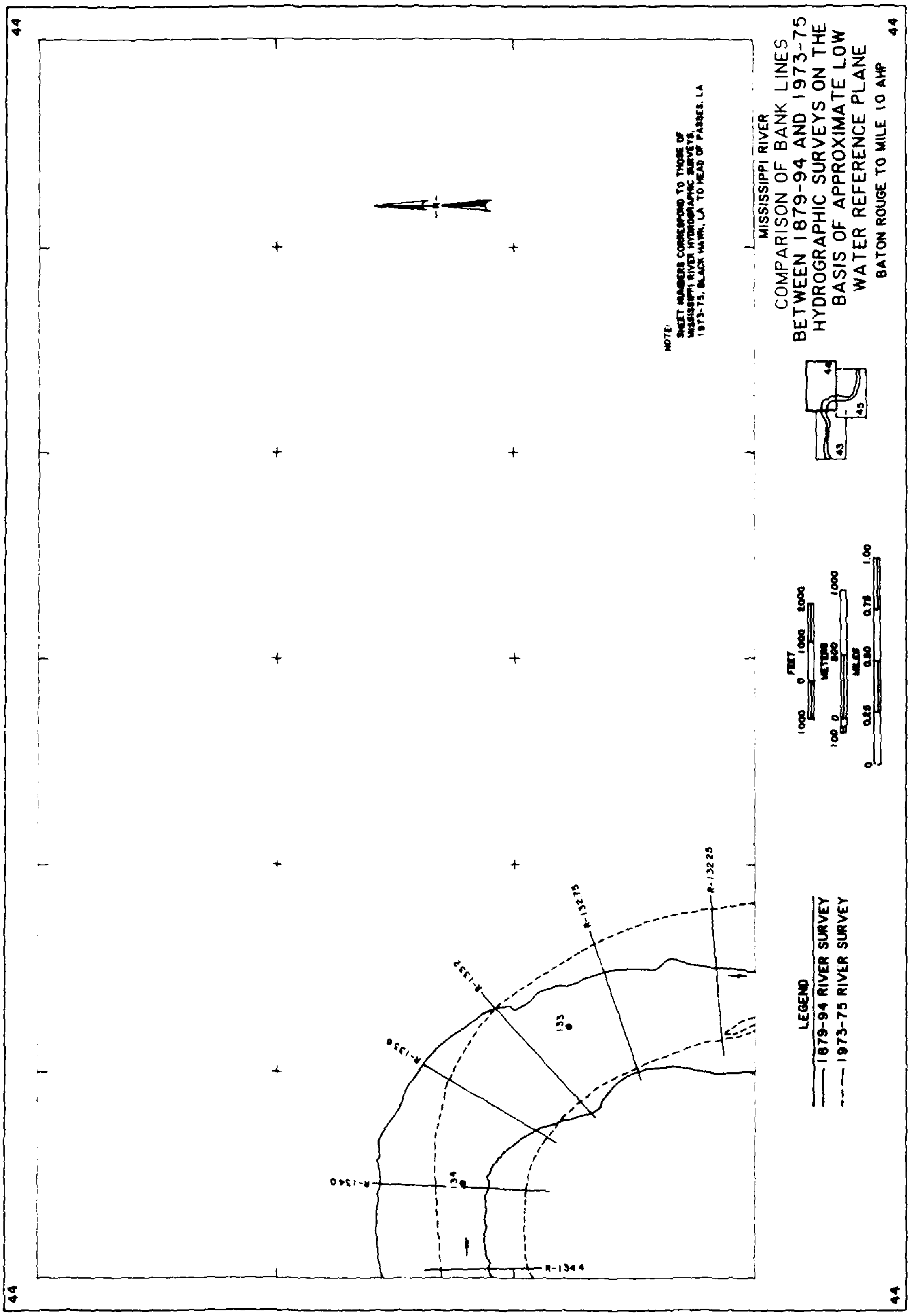

44
NOTE: SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
43
44
45
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
R-132.25
R-132.75
133
134
R-134.4

PLATE A21

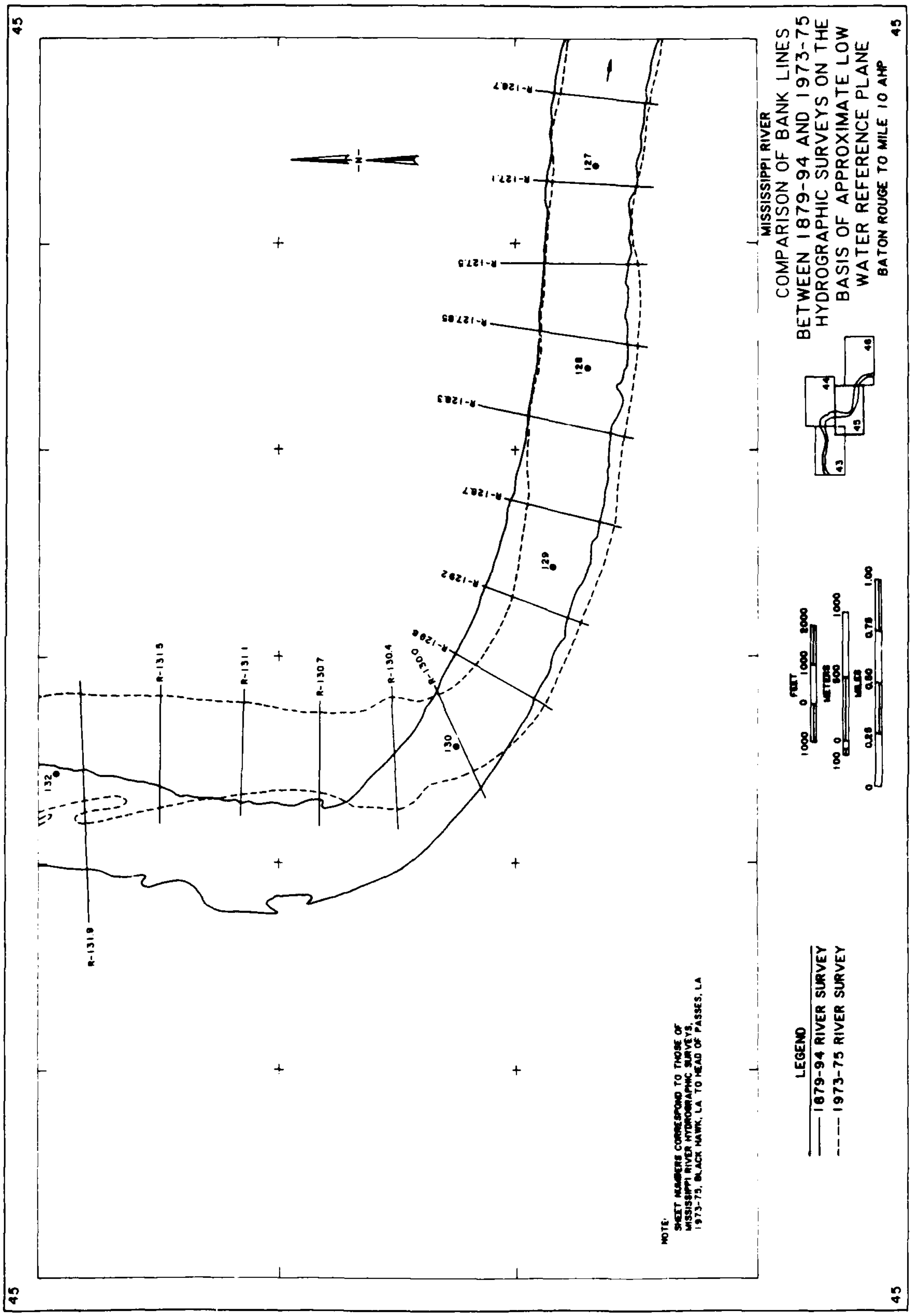

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
45
127
128
129
130
132
R-131.9
R-131.5
R-131.1
R-130.7
R-130.4

PLATE A22

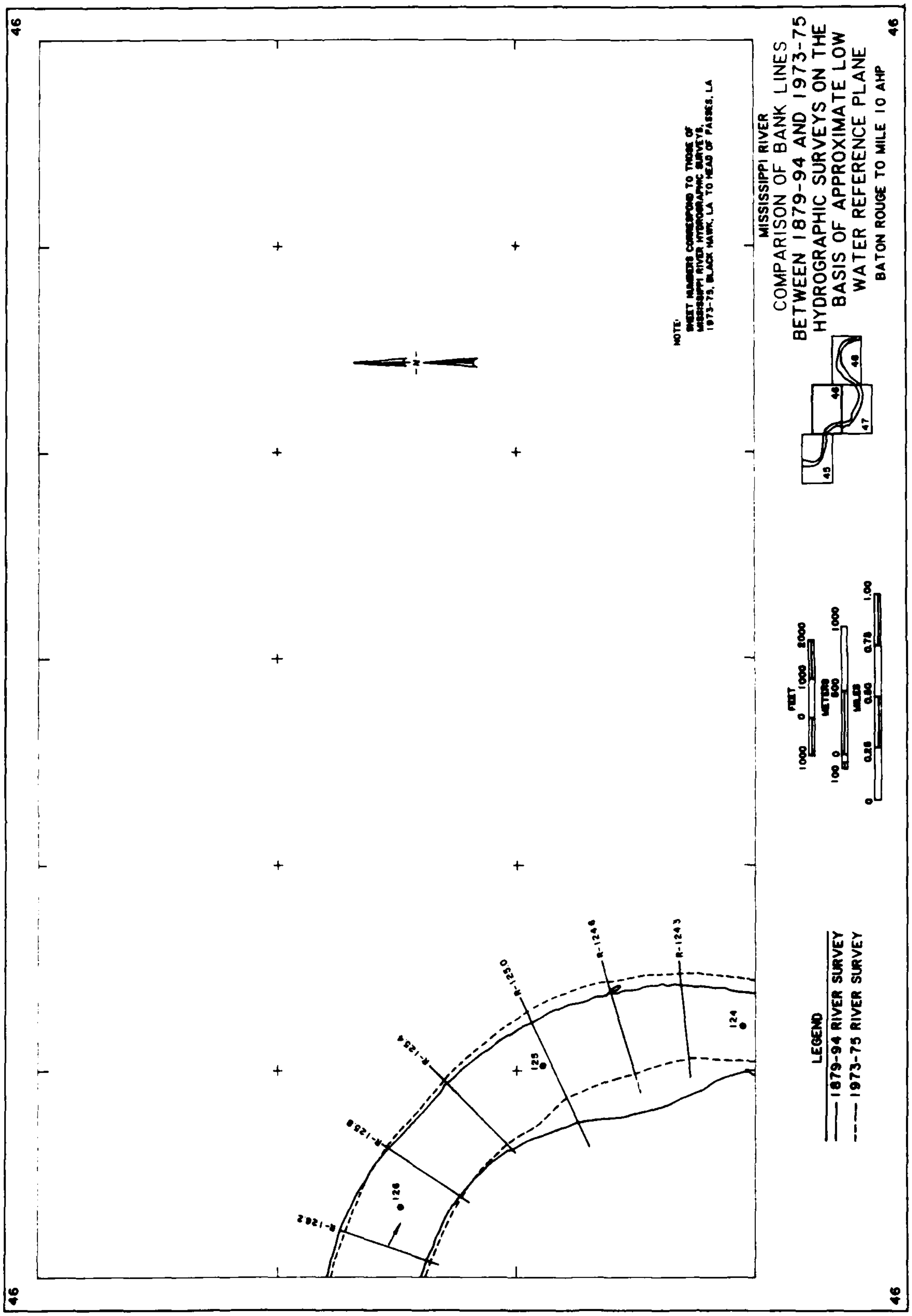
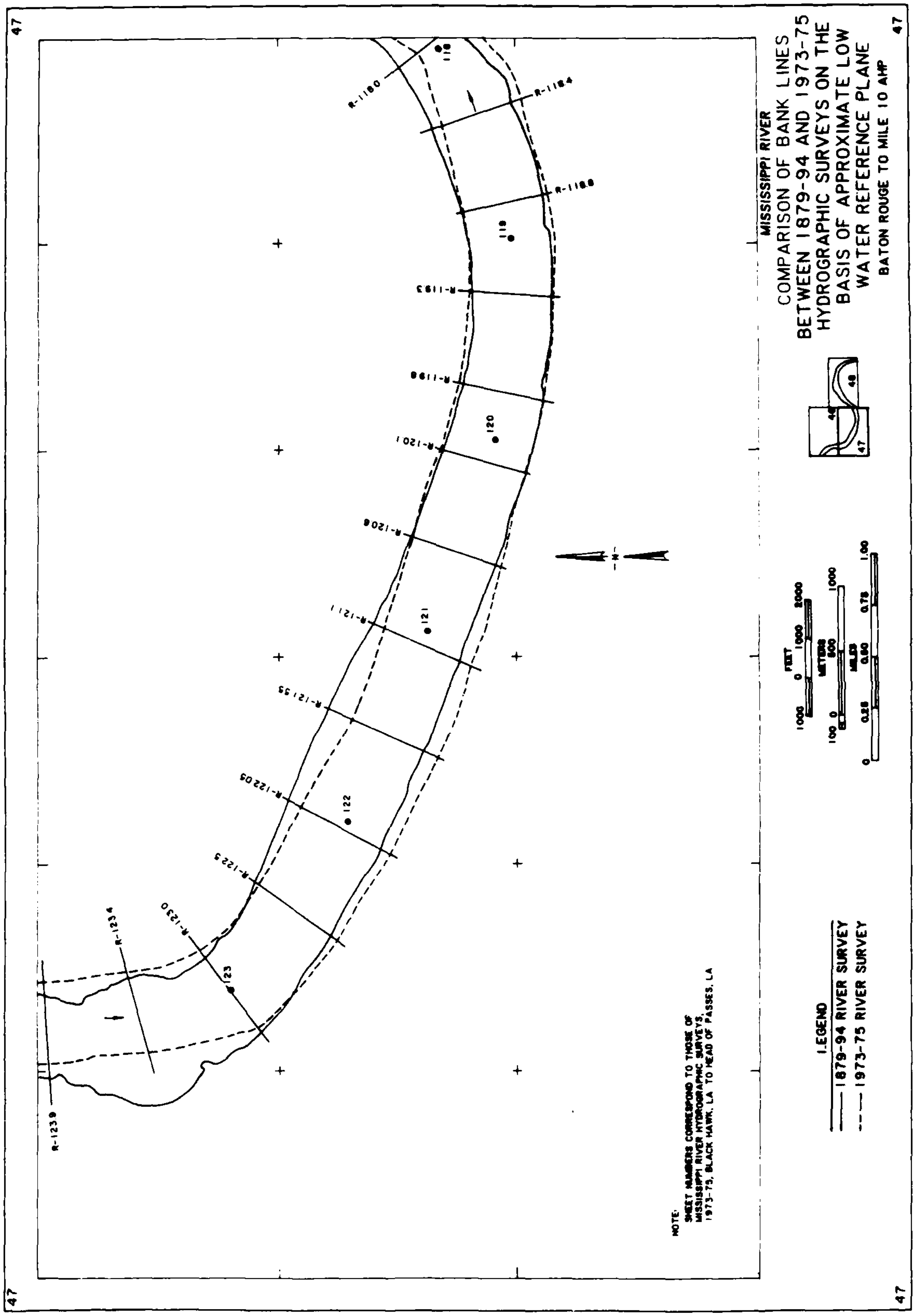

46
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
45
46
47
48
N
R-126.2
R-125.8
R-125.4
R-125.0
R-124.6
R-124.3
126
125
124

PLATE A23



MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
N
47

PLATE A24

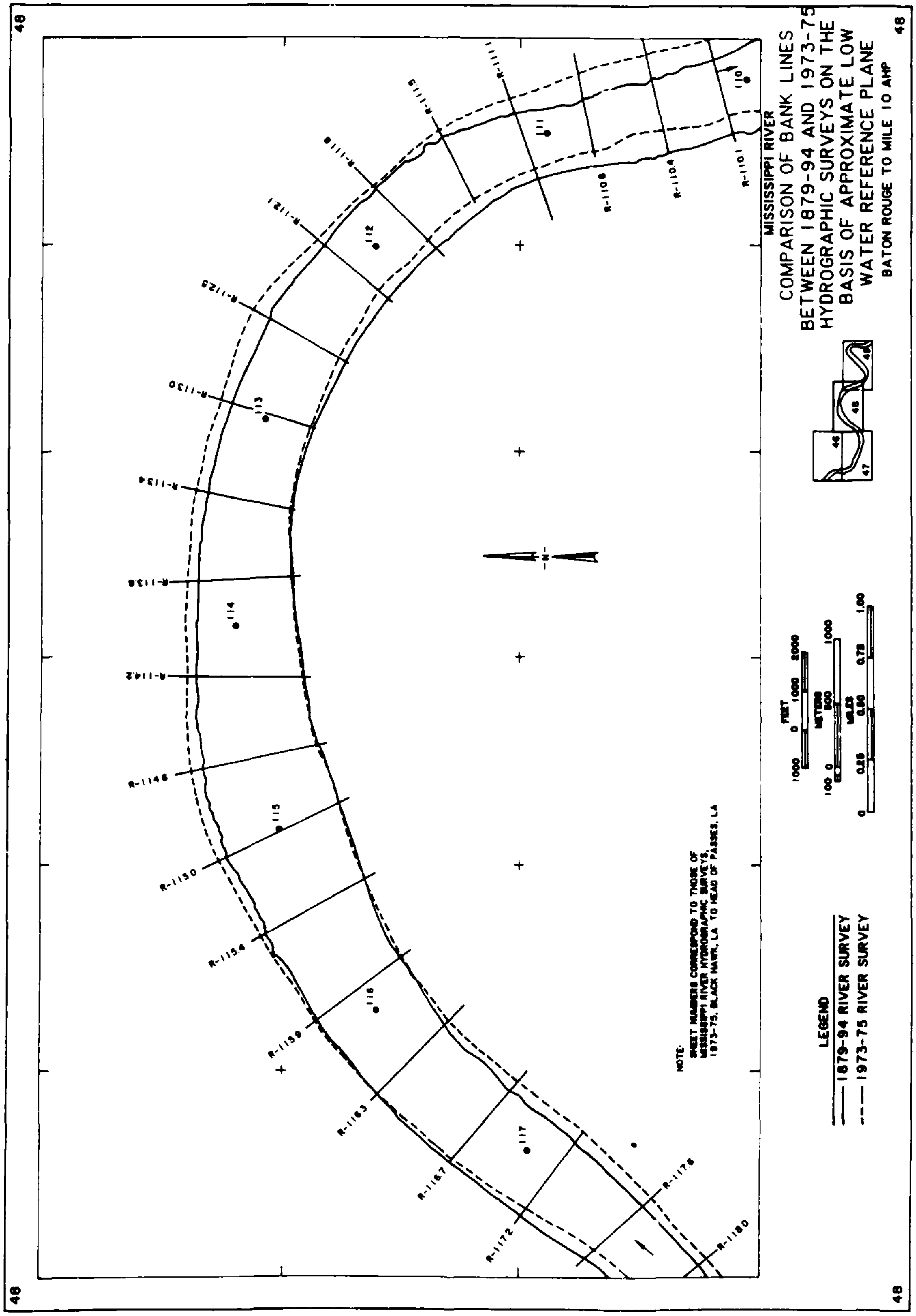

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
48

PLATE A25

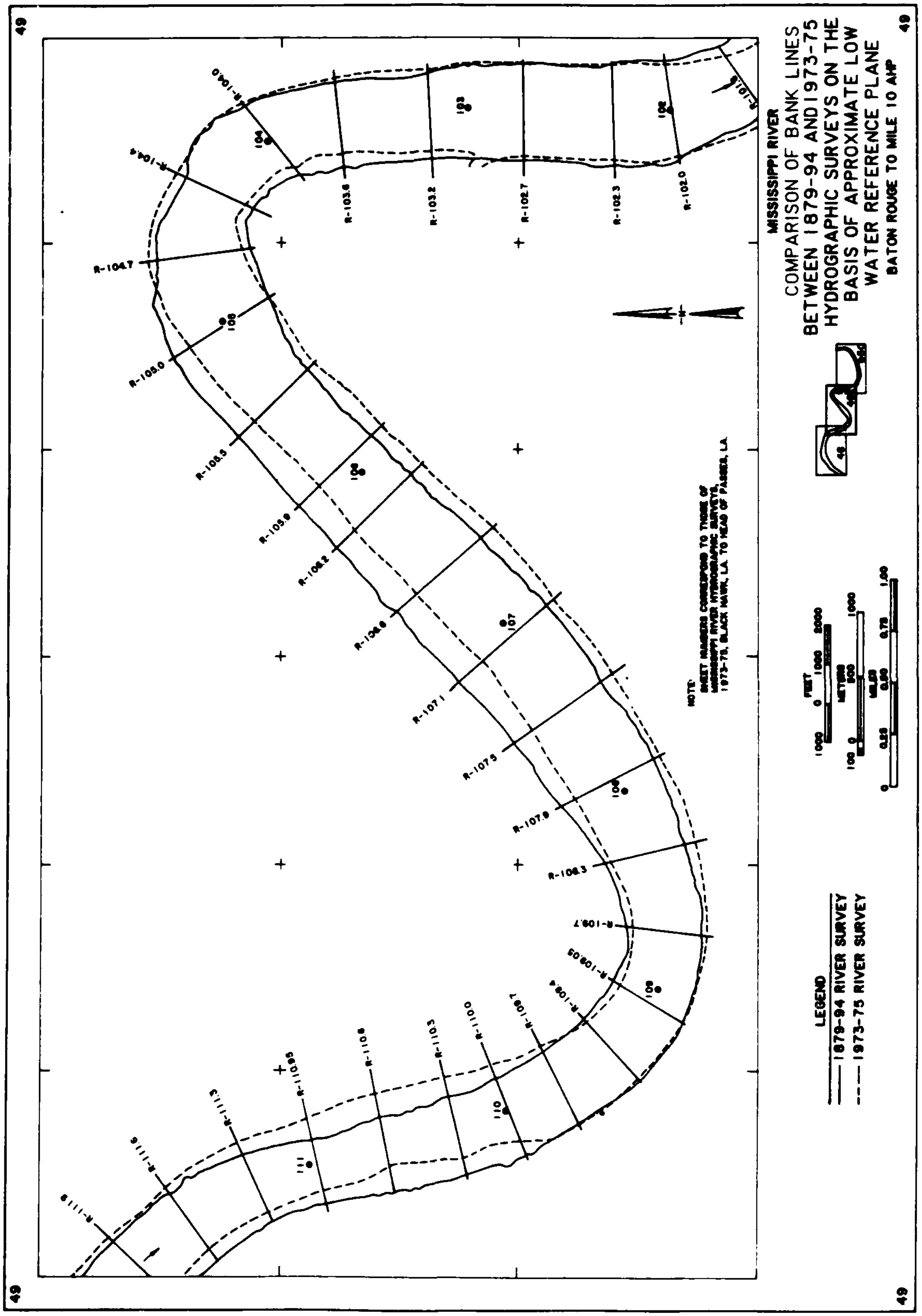

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.
49

PLATE A26

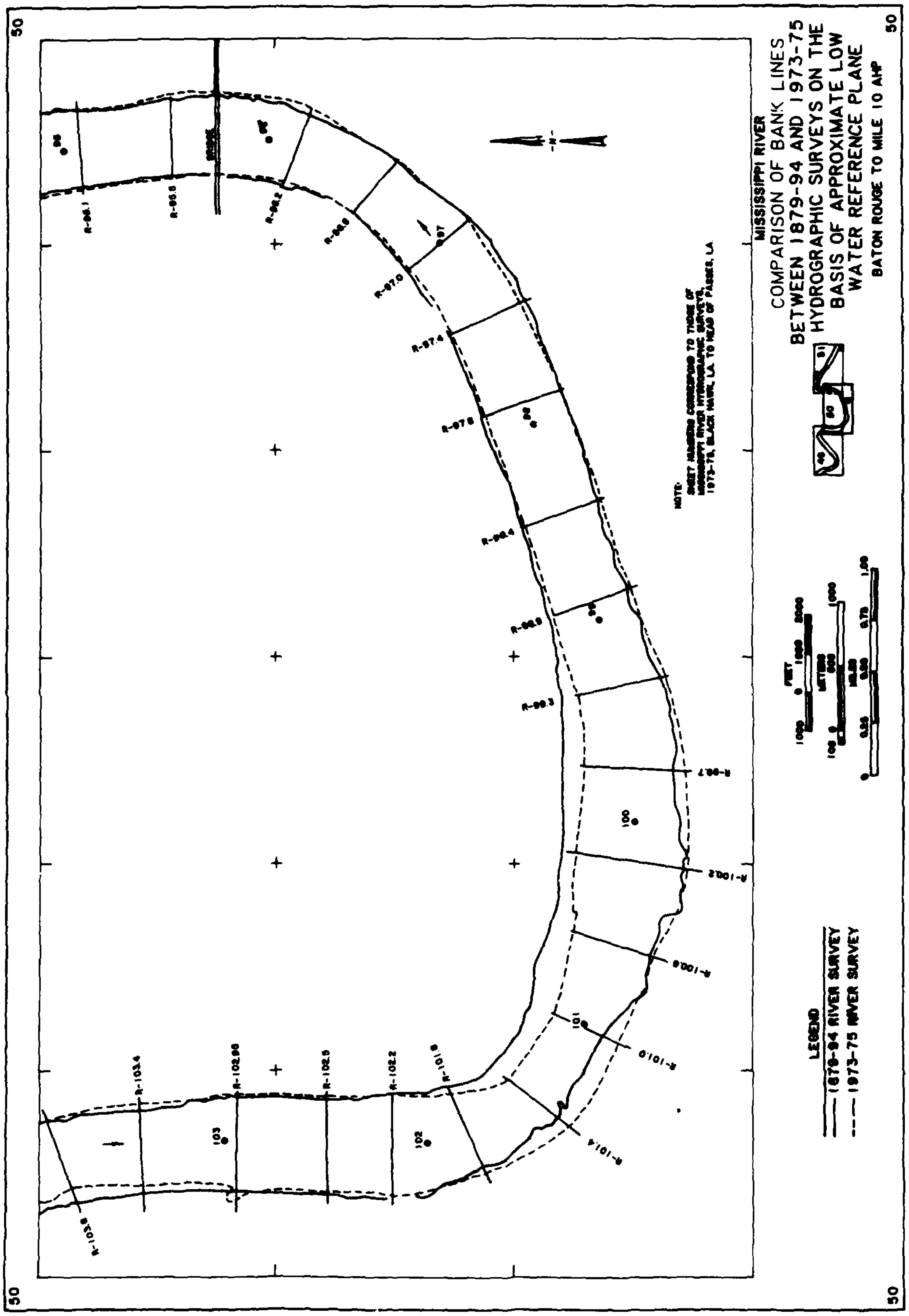

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
50
50
50
50

PLATE A27

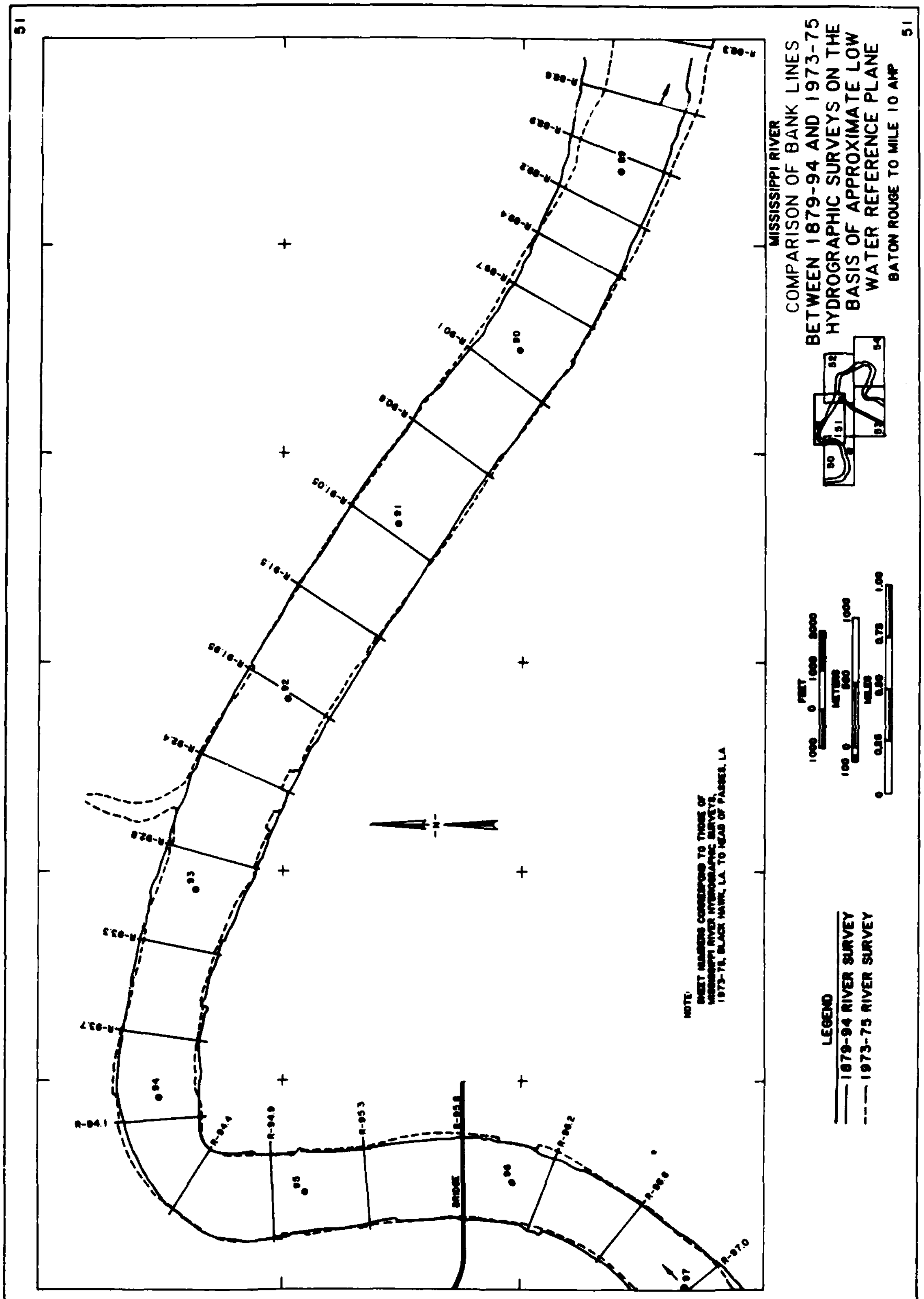
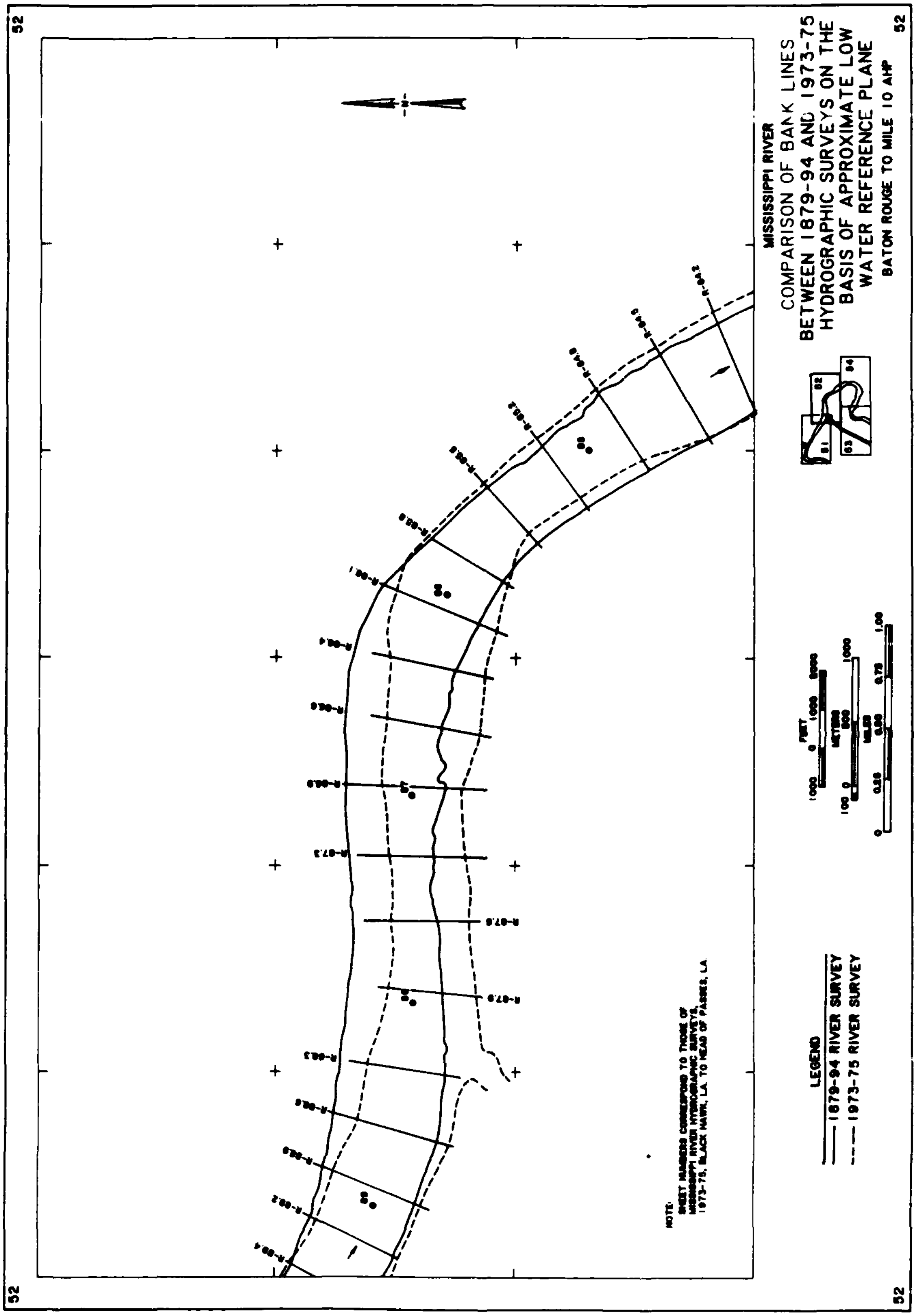

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.
BRIDGE
51

PLATE A28



MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.
52

PLATE A29

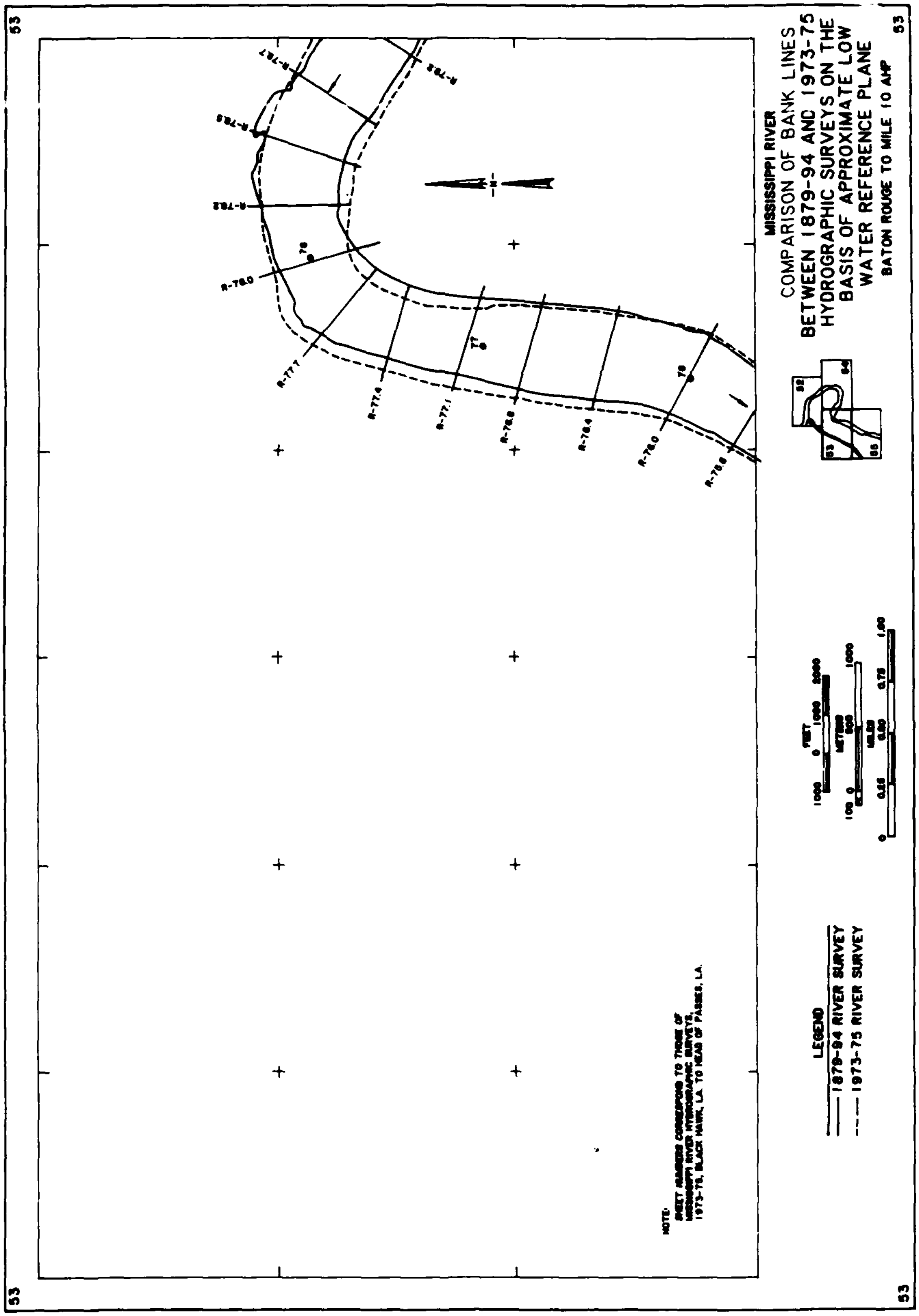

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA.
53

PLATE A30

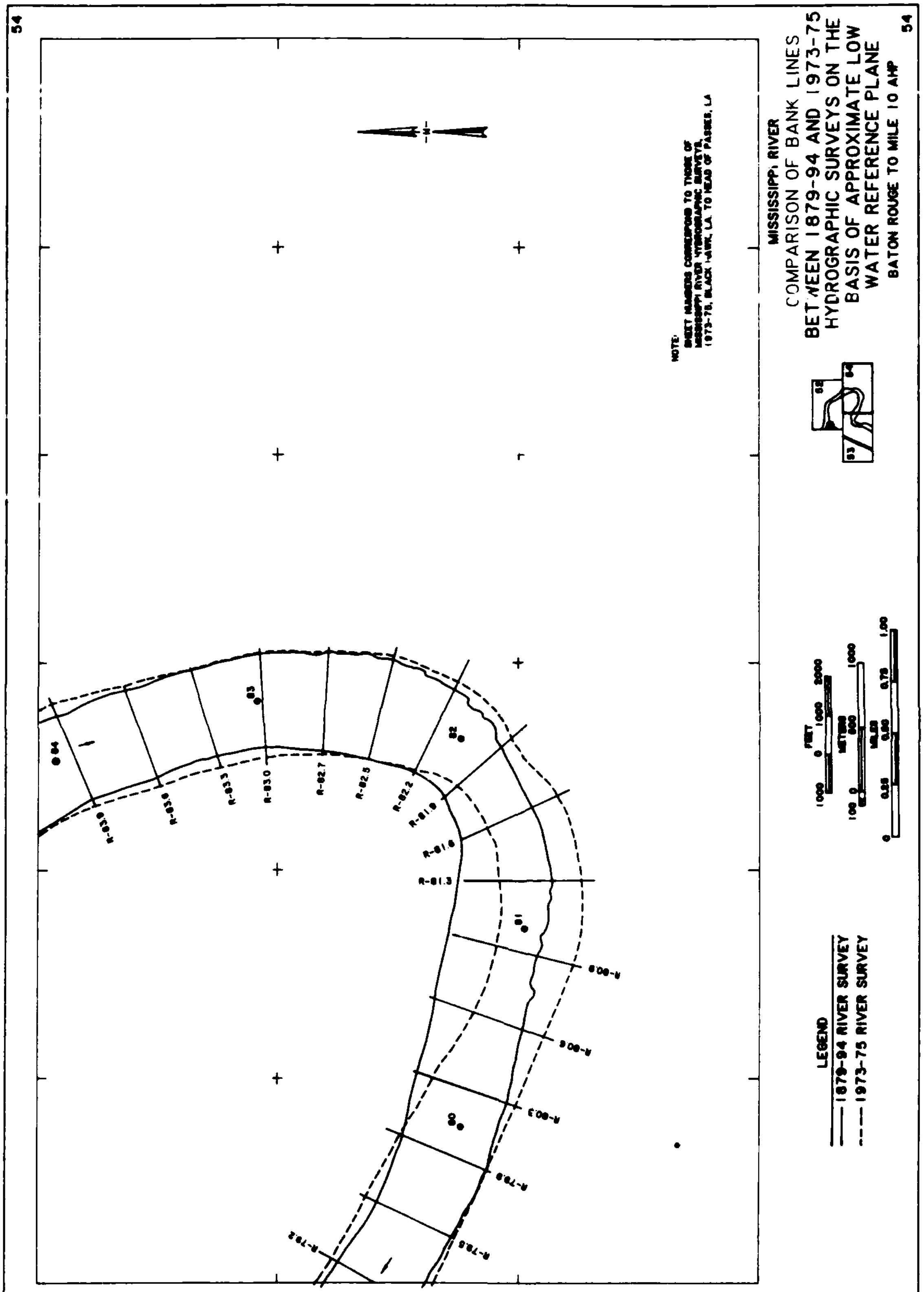

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
54

PLATE A31

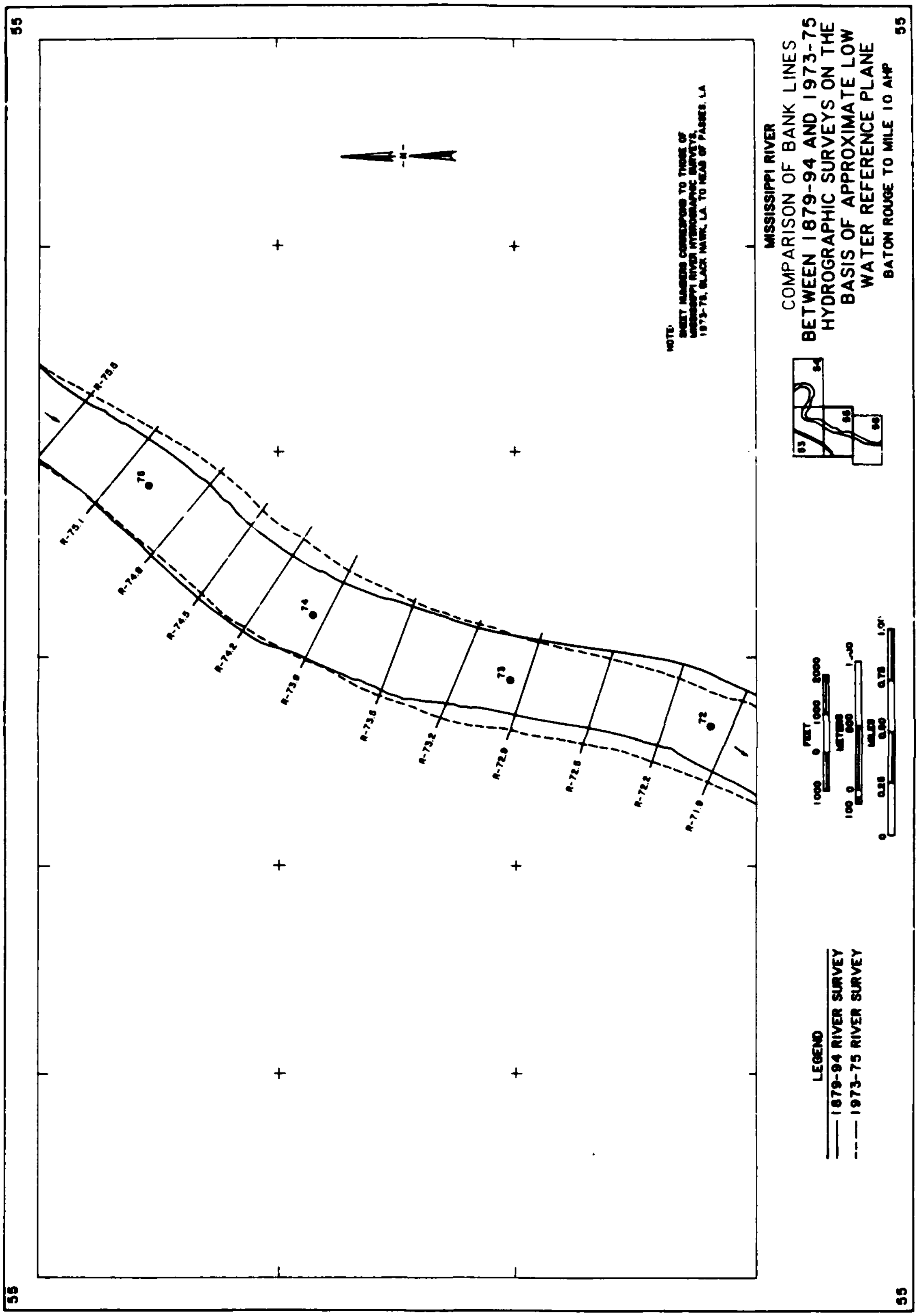

55
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES
R-75.6
R-75.1
R-74.8
R-74.5
R-74.2
R-73.9
R-73.5
R-73.2
R-72.9
R-72.5
R-72.2
R-71.9
75
74
73
72

PLATE A32

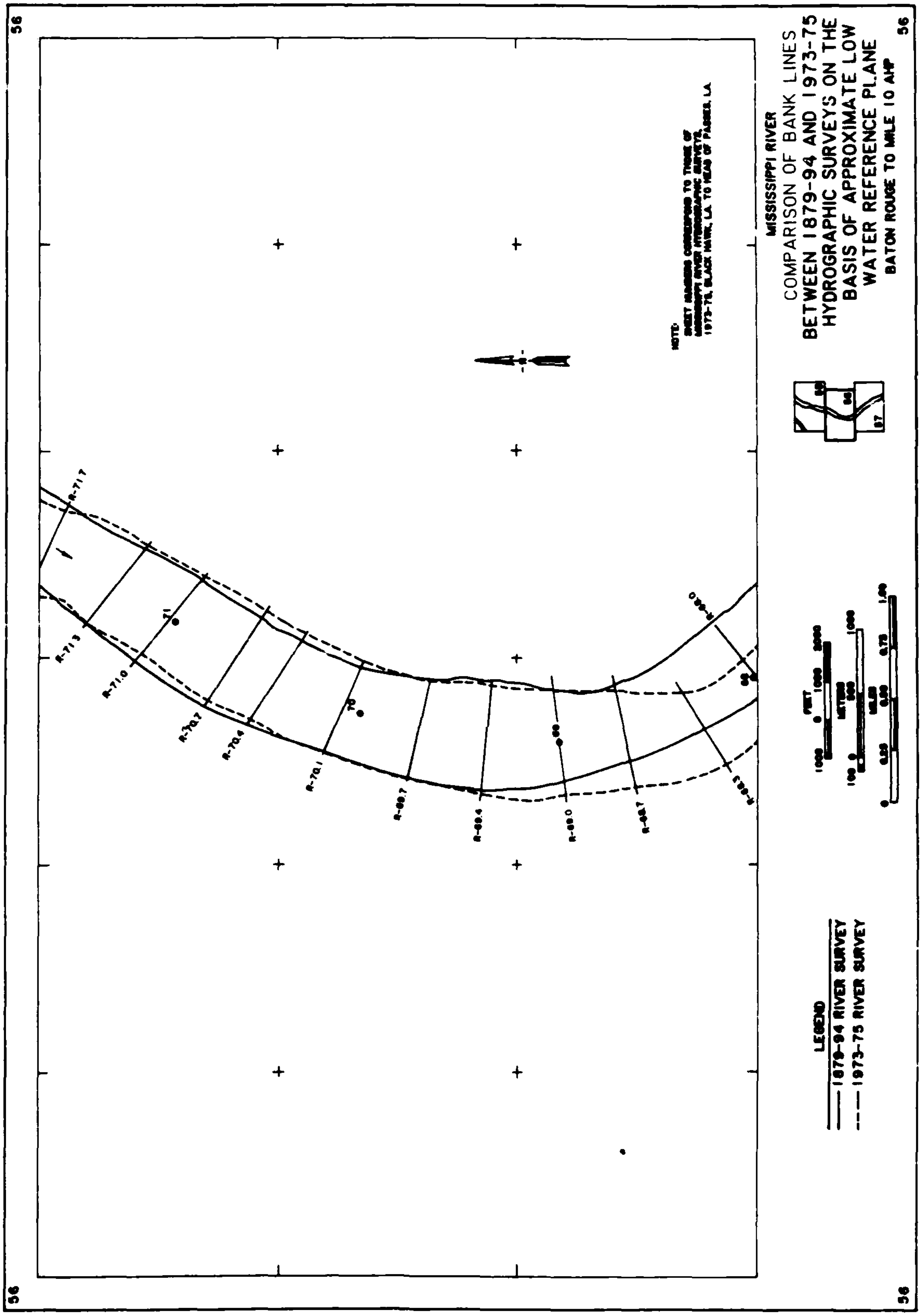

56
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
R-71.7
R-71.3
R-71.0
R-70.7
R-70.4
R-70.1
R-69.7
R-69.4
R-69.0
R-68.7
R-68.3
71
70
69
FEET
METERS
MILES
1.00

PLATE A33

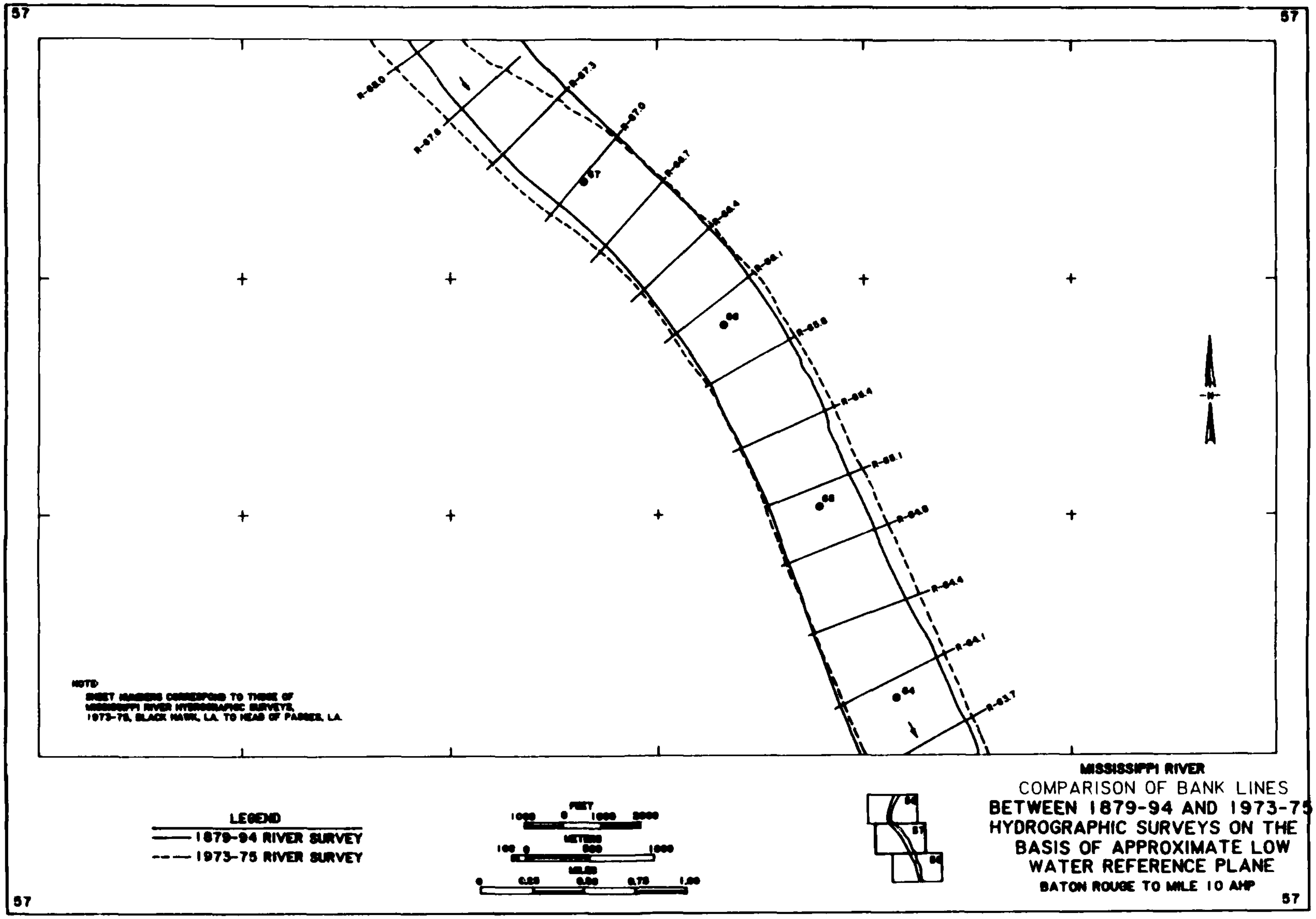
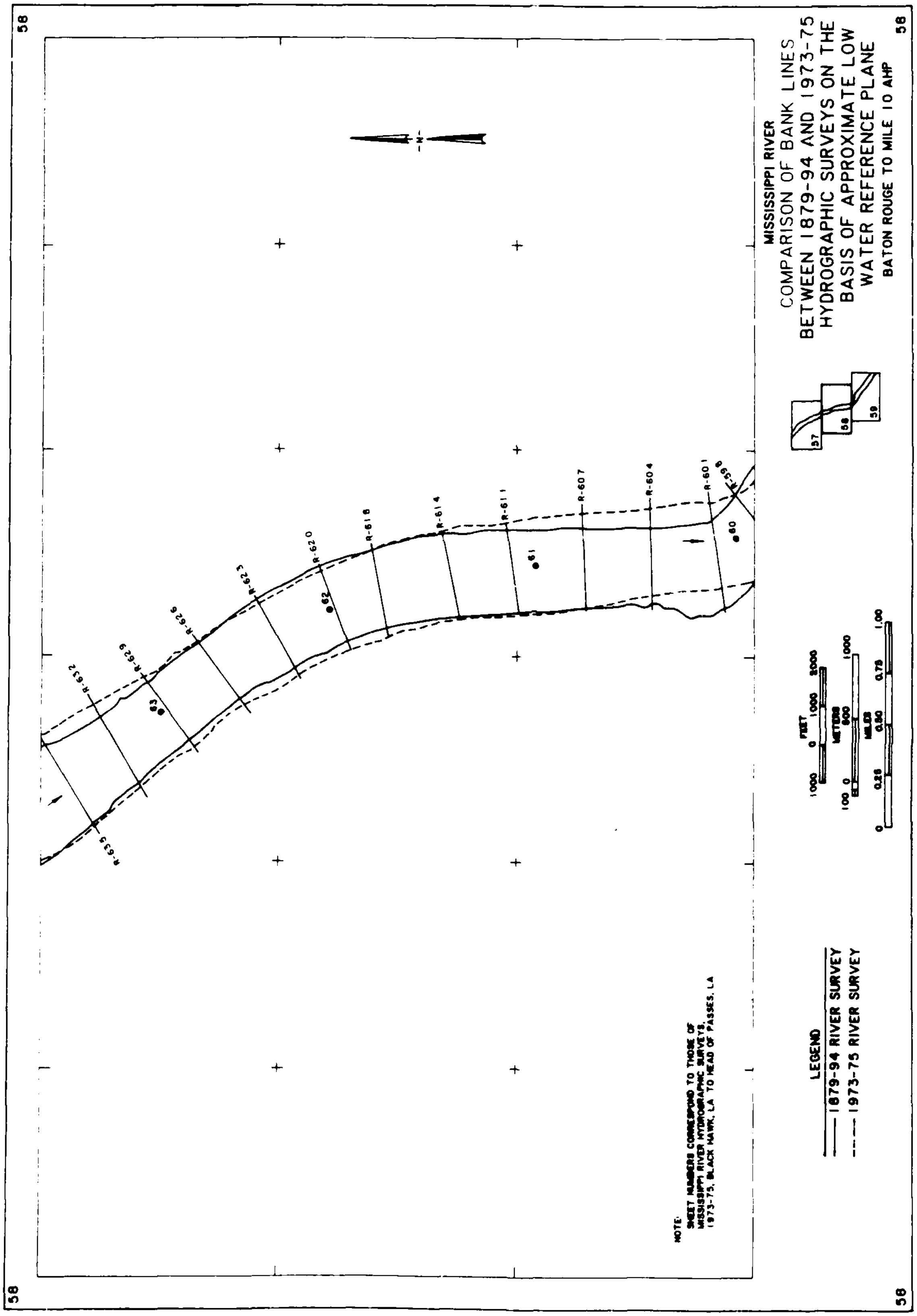

57
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.
FEET
METERS
MILES

PLATE A34



58
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
57
58
59
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
R-601
R-604
R-607
R-611
R-614
R-618
R-620
R-623
R-626
R-629
R-632
R-635
60
61
62
63

PLATE A35

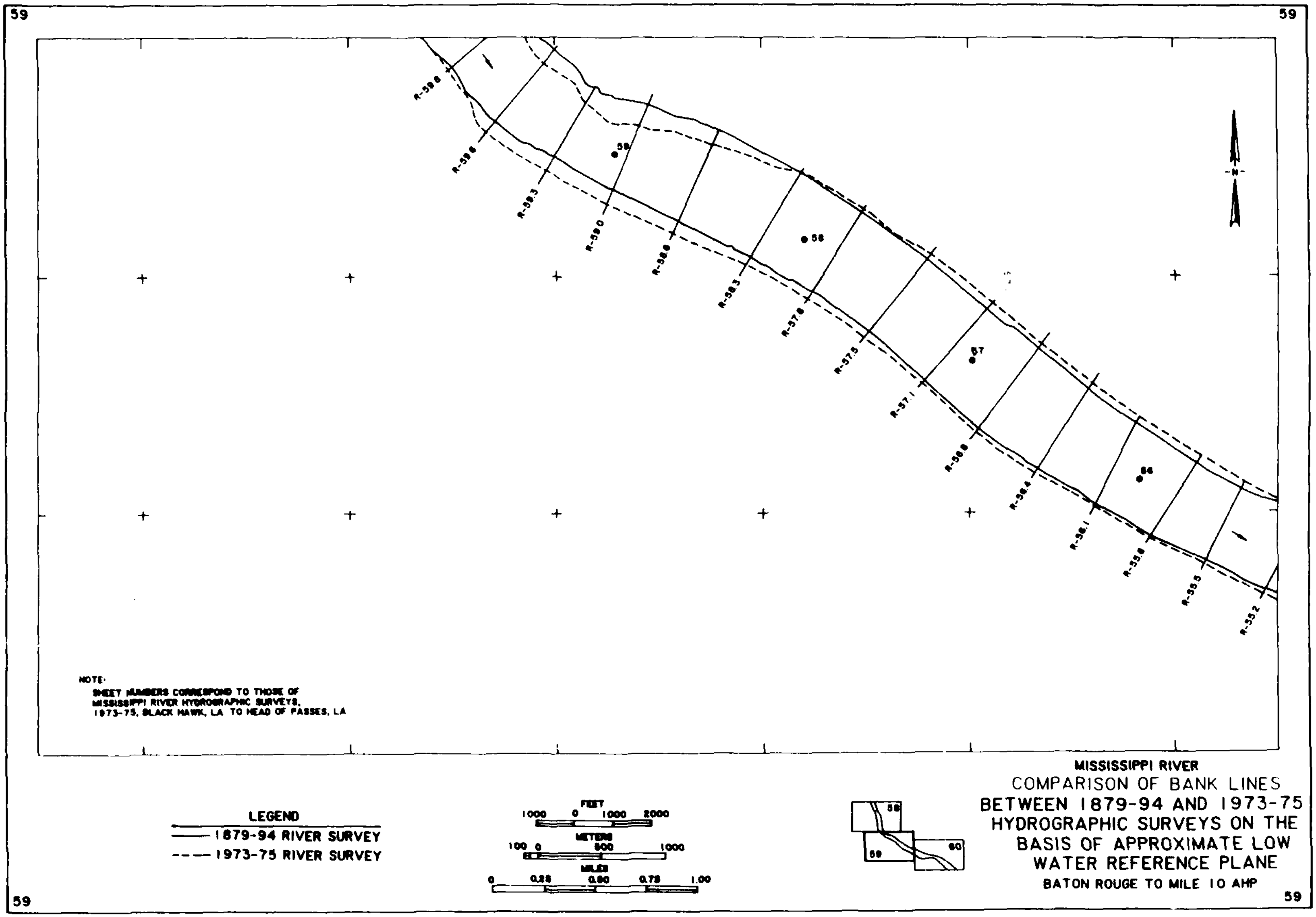

59
59
59
59
N
R-59.8
R-59.6
R-59.3
R-59.0
R-58.6
R-58.3
R-57.8
R-57.5
R-57.1
R-56.8
R-56.4
R-56.1
R-55.8
R-55.5
R-55.2
59
58
57
56
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
58
59
60
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP

PLATE A36

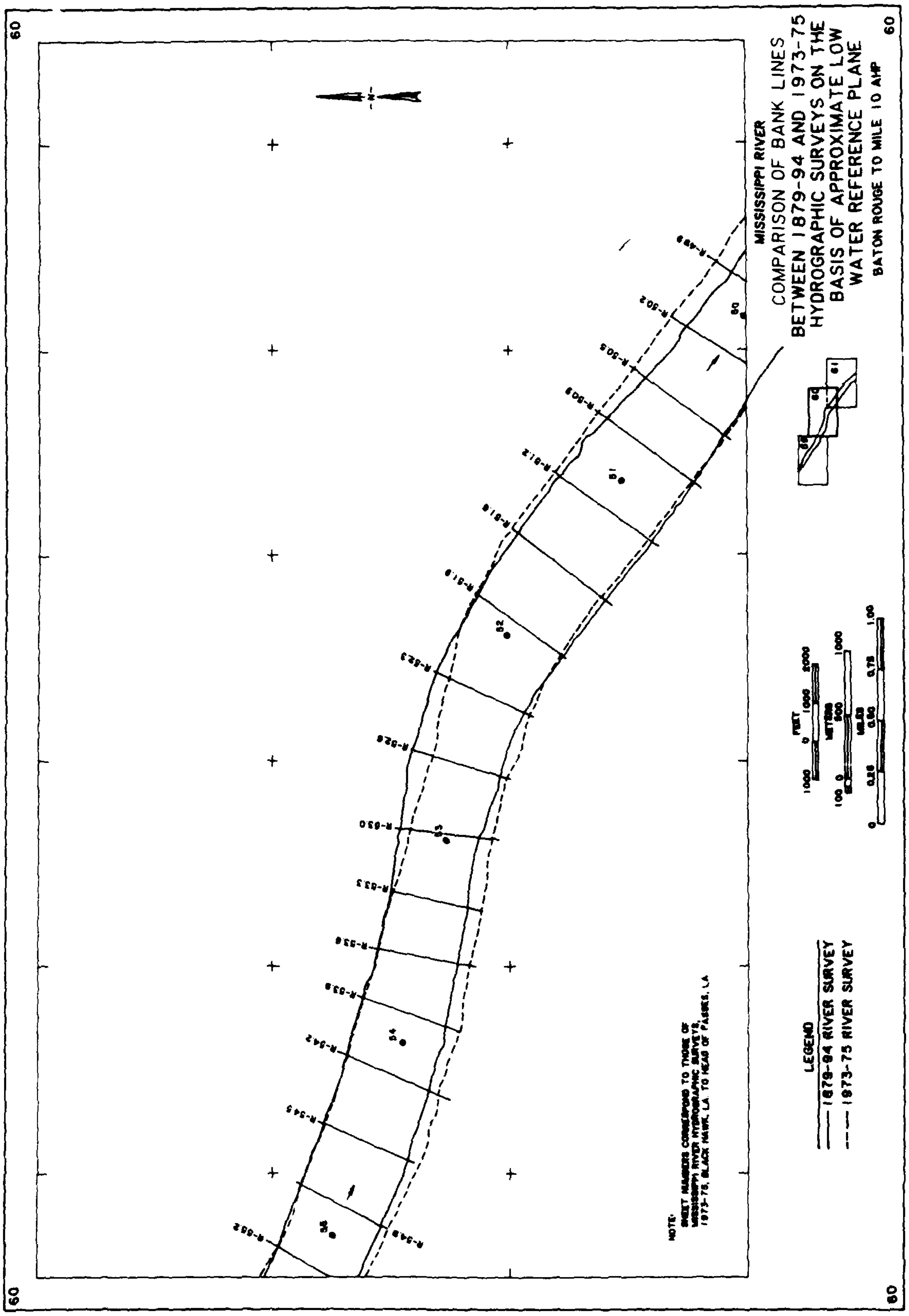
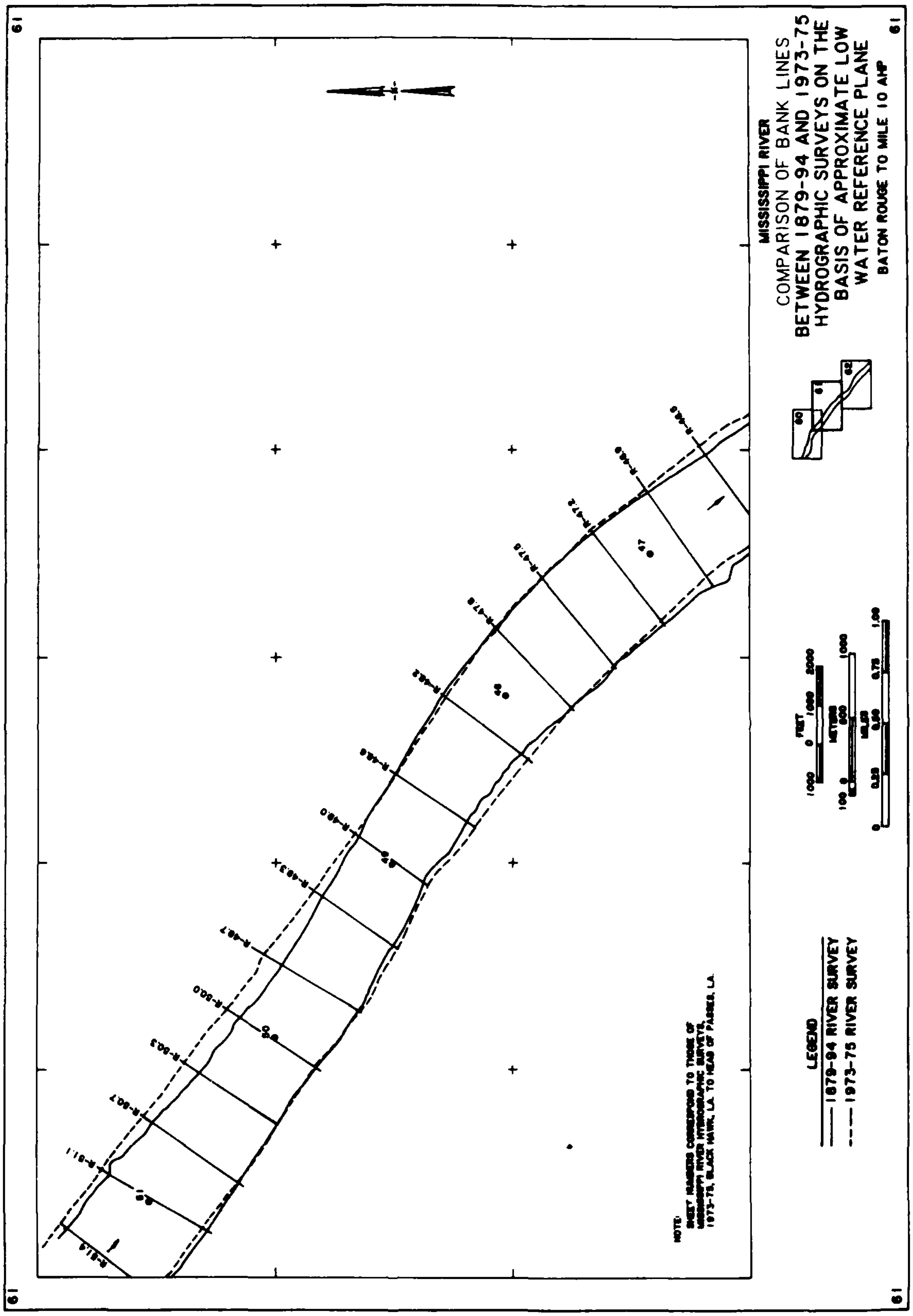

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES

PLATE A37



MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.

PLATE A38

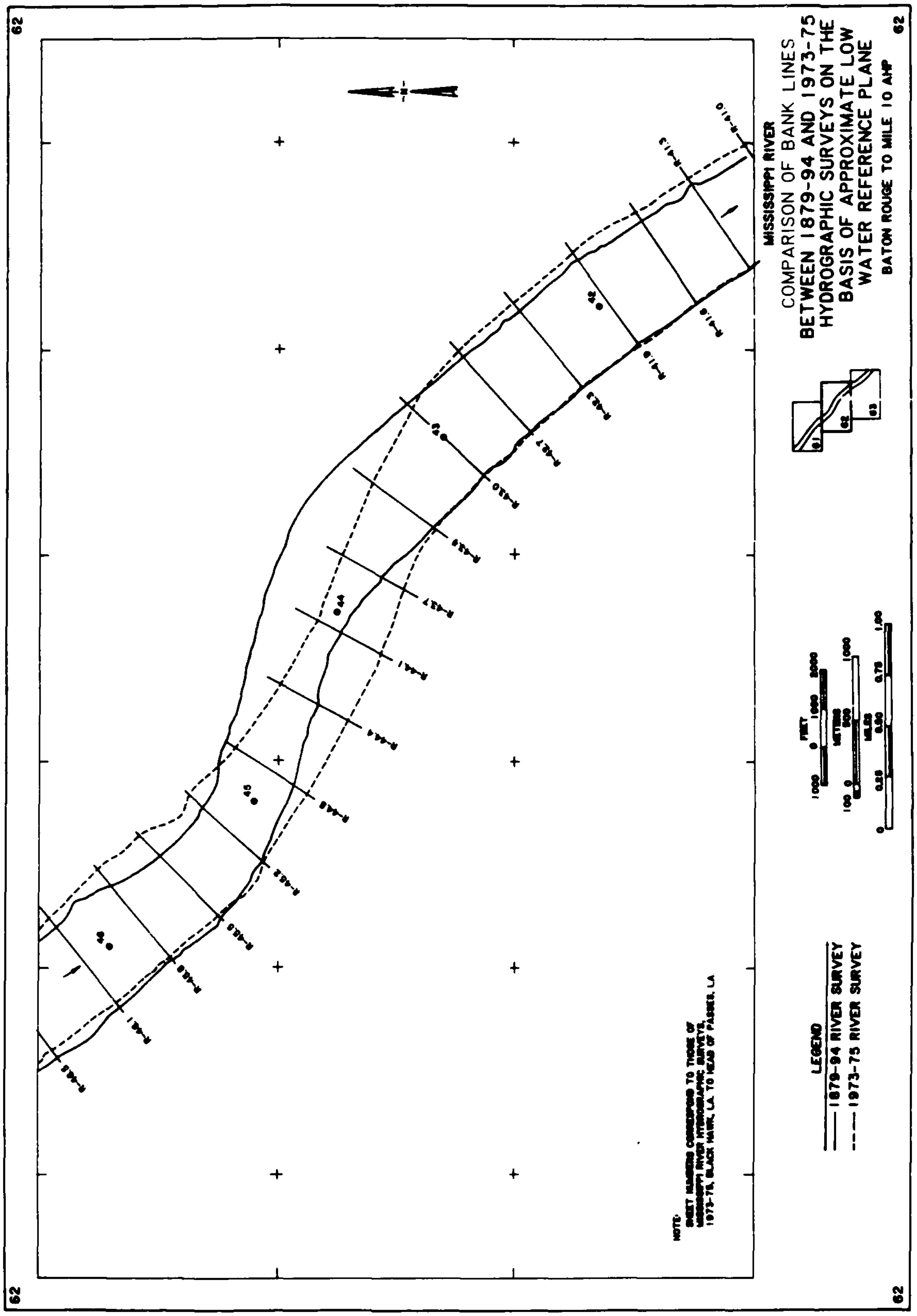

62
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.
FEET
METERS
MILES

PLATE A39

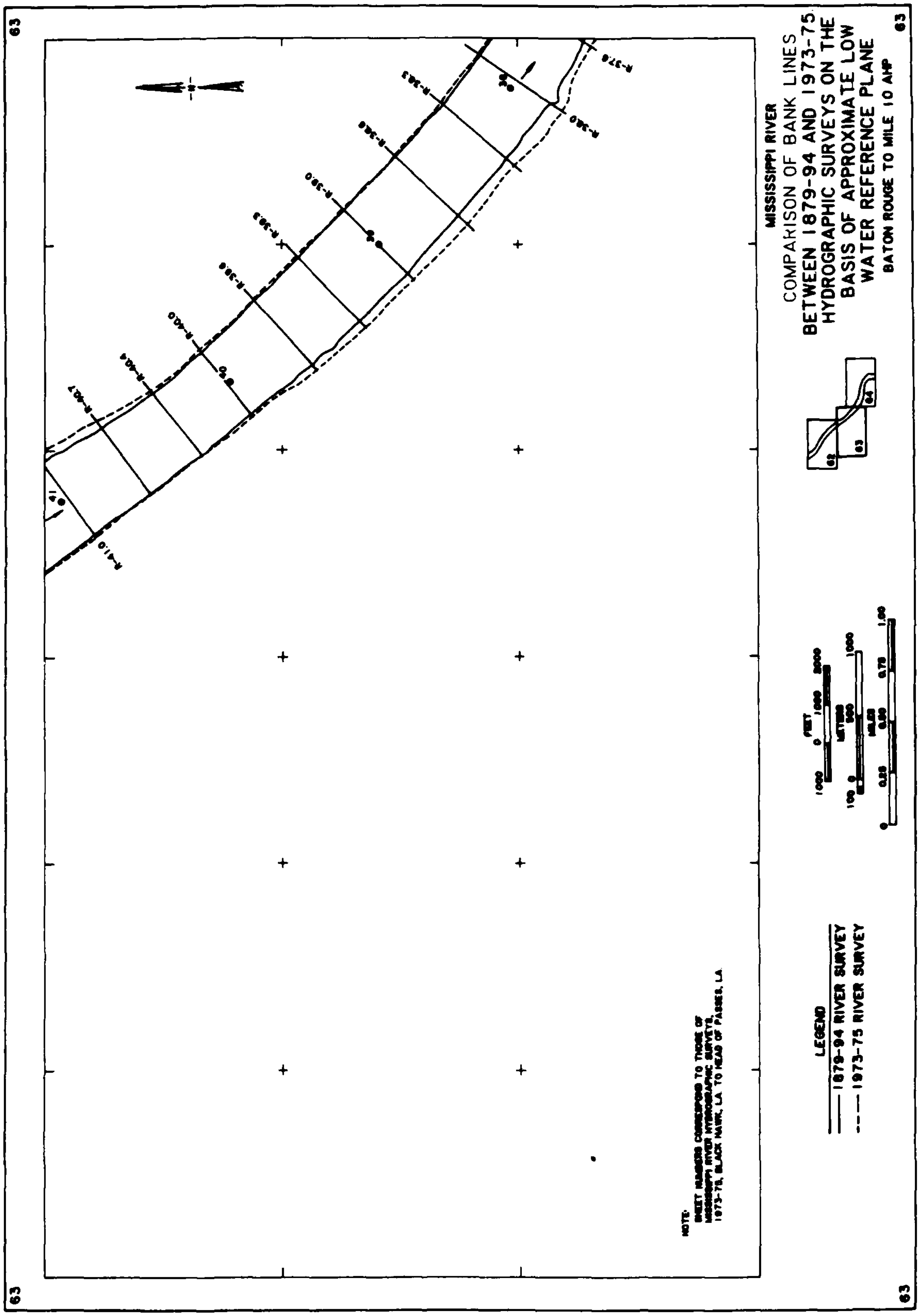

63
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
62
63
64

PLATE A40

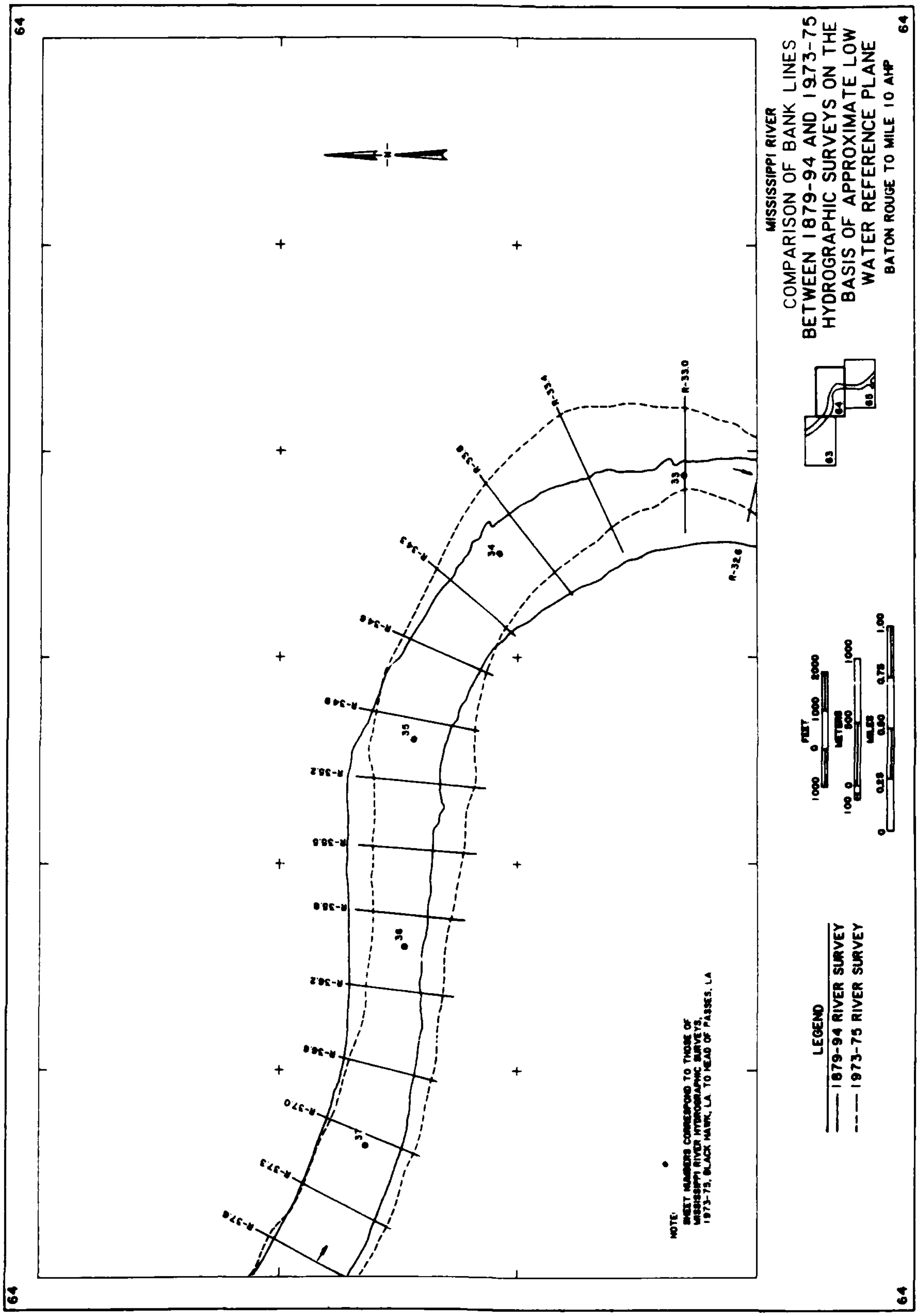

64
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
R-33.0
R-33.4
R-33.8
R-34.3
R-34.6
R-34.9
R-35.2
R-35.5
R-35.8
R-36.2
R-36.6
R-37.0
R-37.3
R-37.6
R-32.6
33
34
35
36
37
63
64
65

PLATE A41

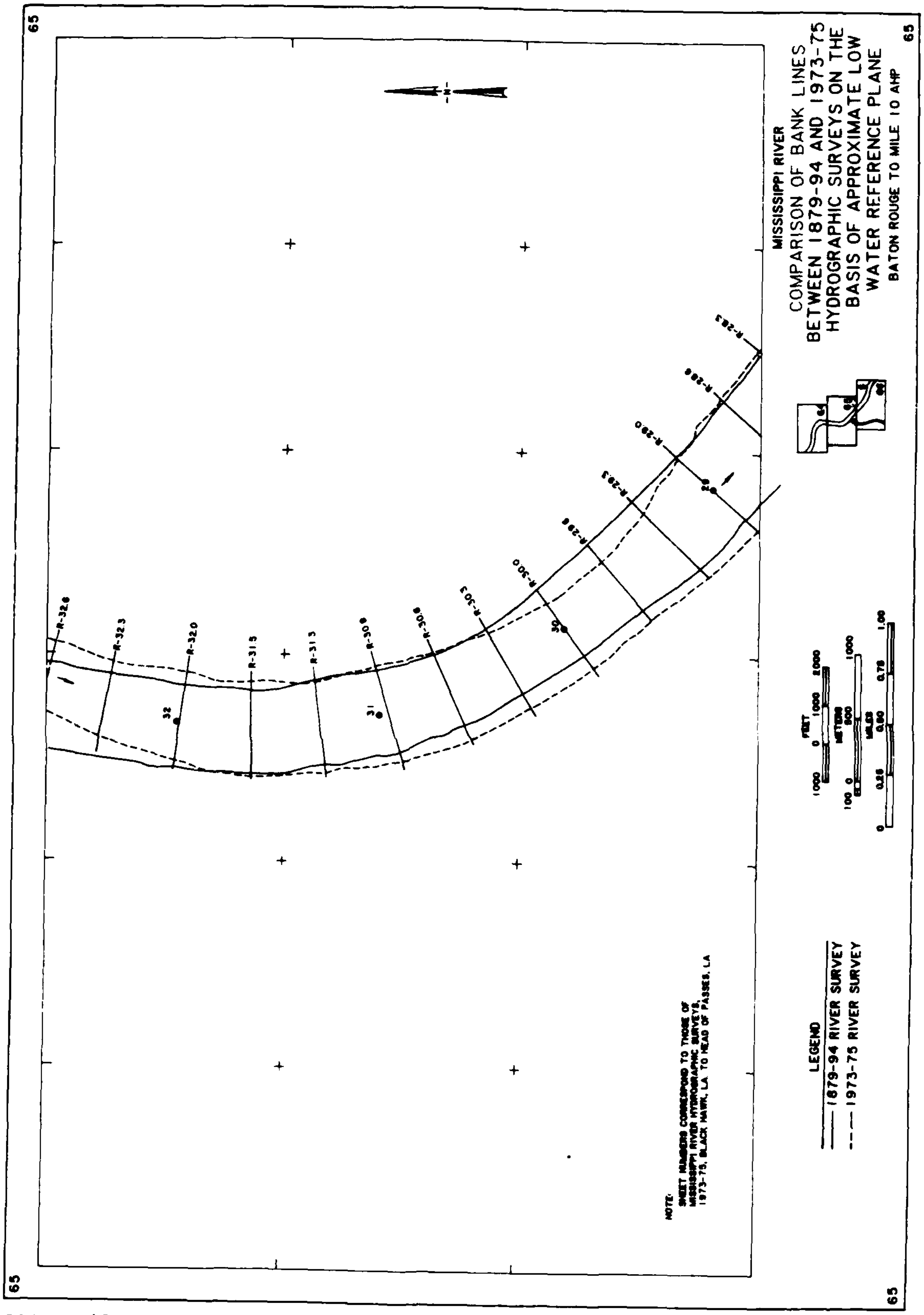

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
FEET
METERS
MILES
65

PLATE A42

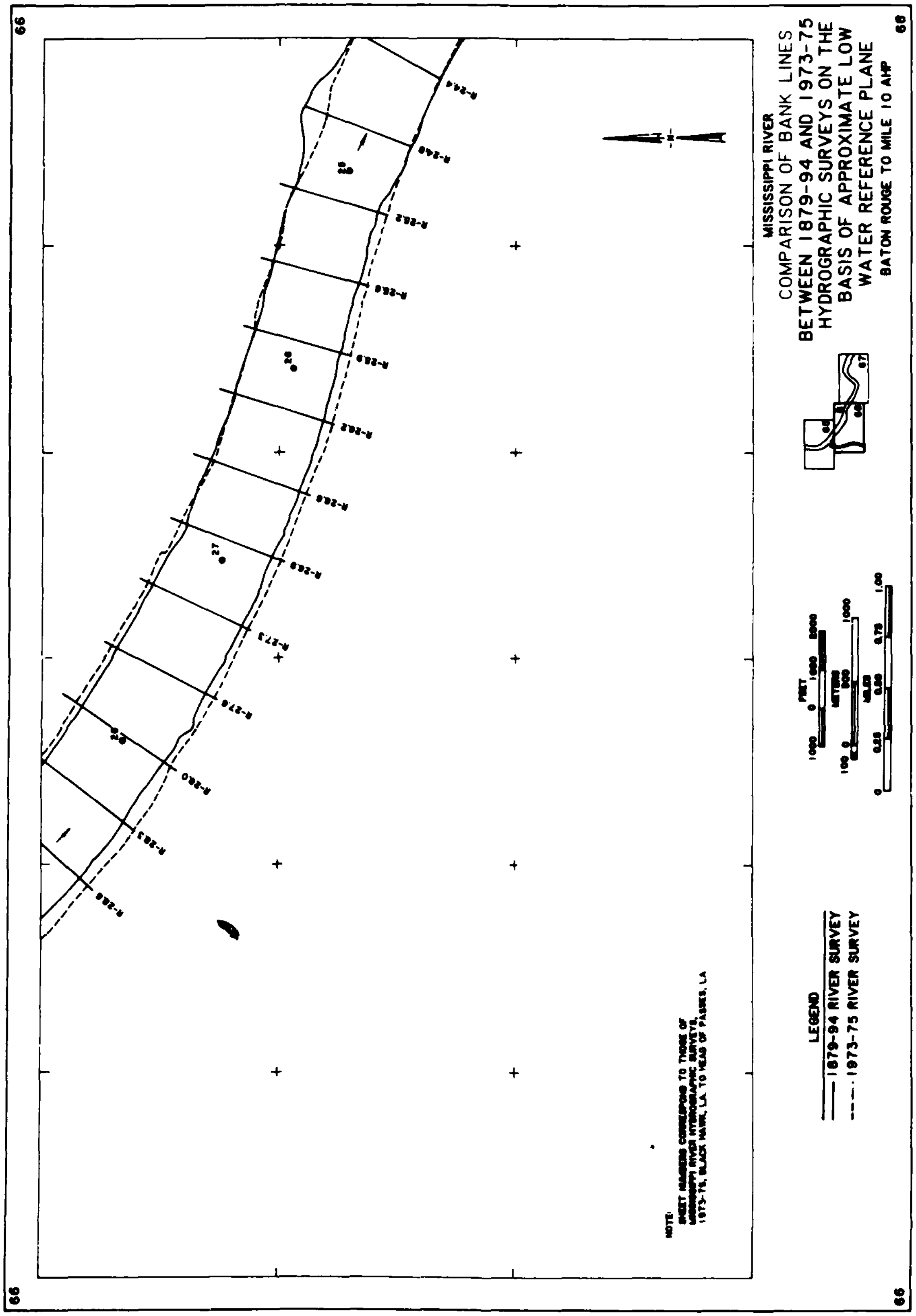

66
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
FEET
METERS
MILES
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.

PLATE A43

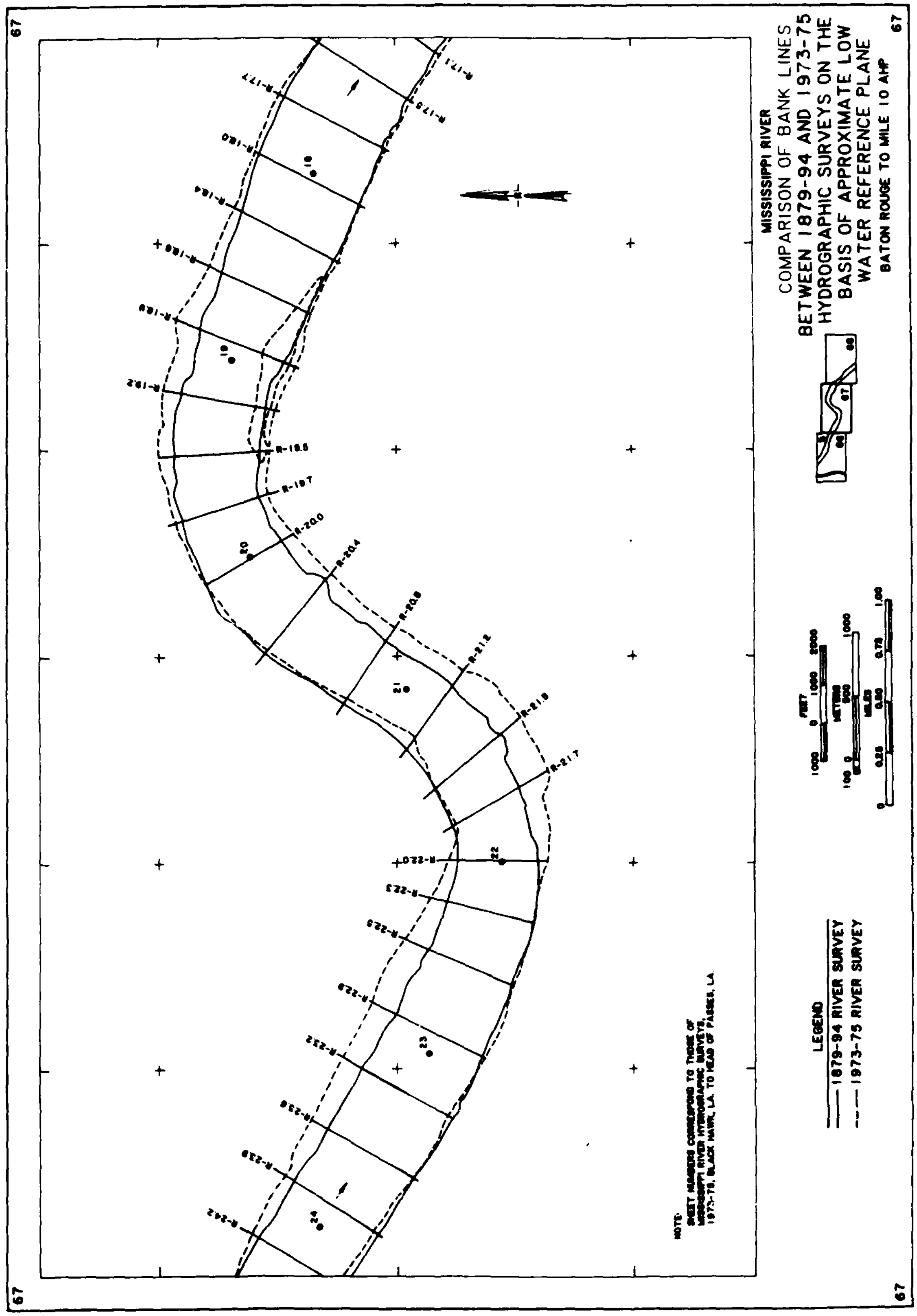

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
67

PLATE A44

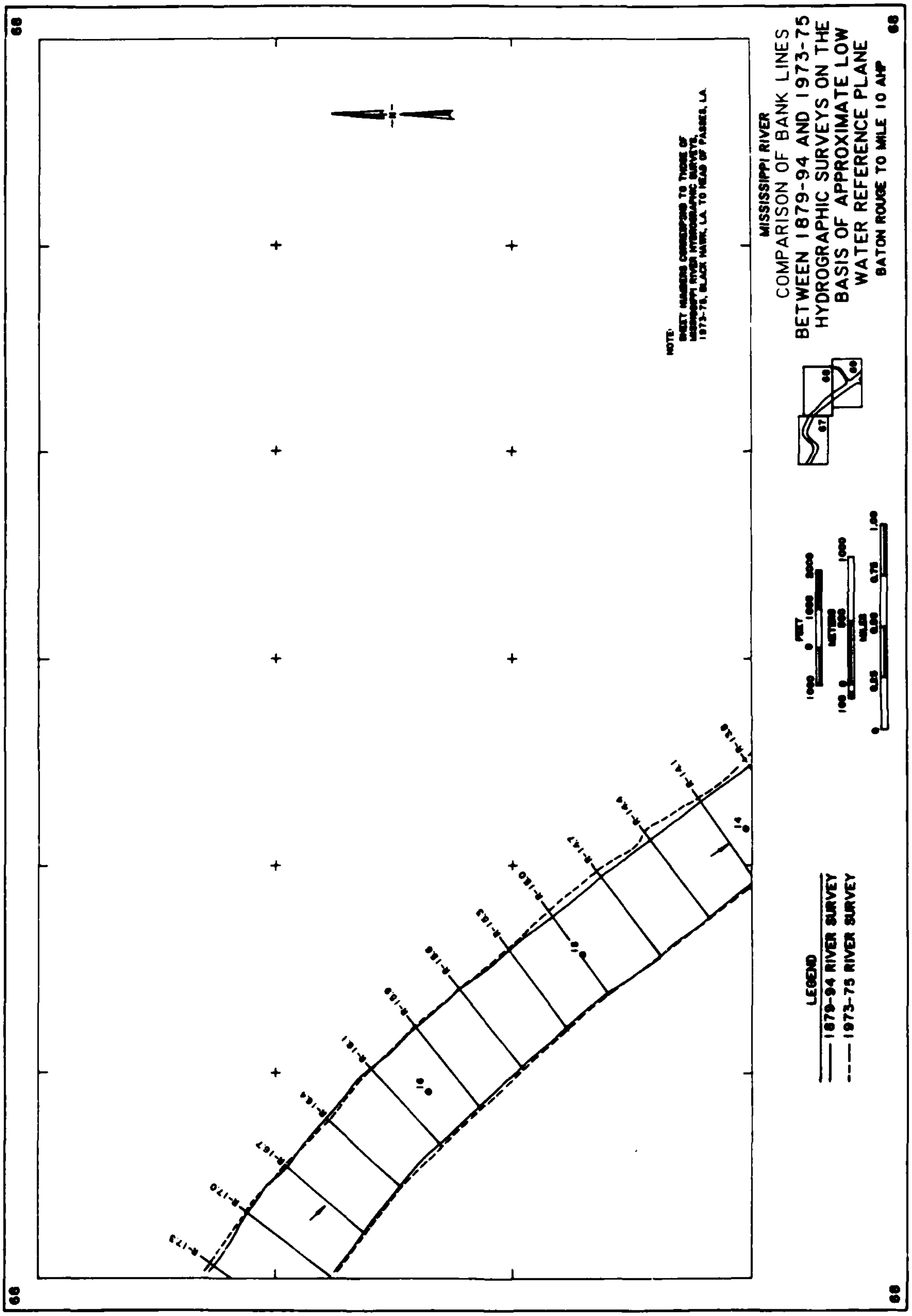
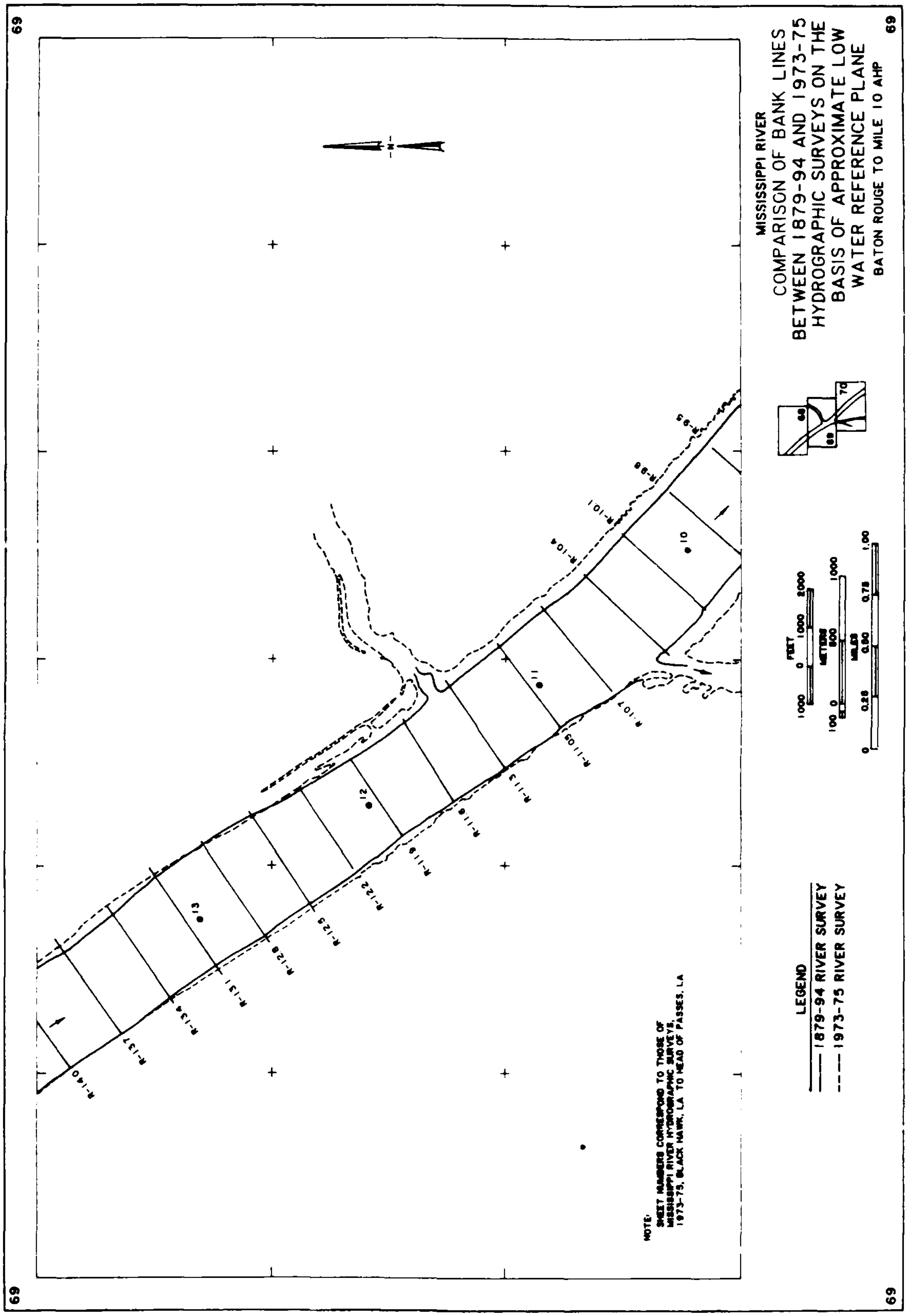

MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA. TO HEAD OF PASSES, LA.
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES
68

PLATE A45



MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
FEET
METERS
MILES
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF
MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS,
1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA
69

PLATE A46

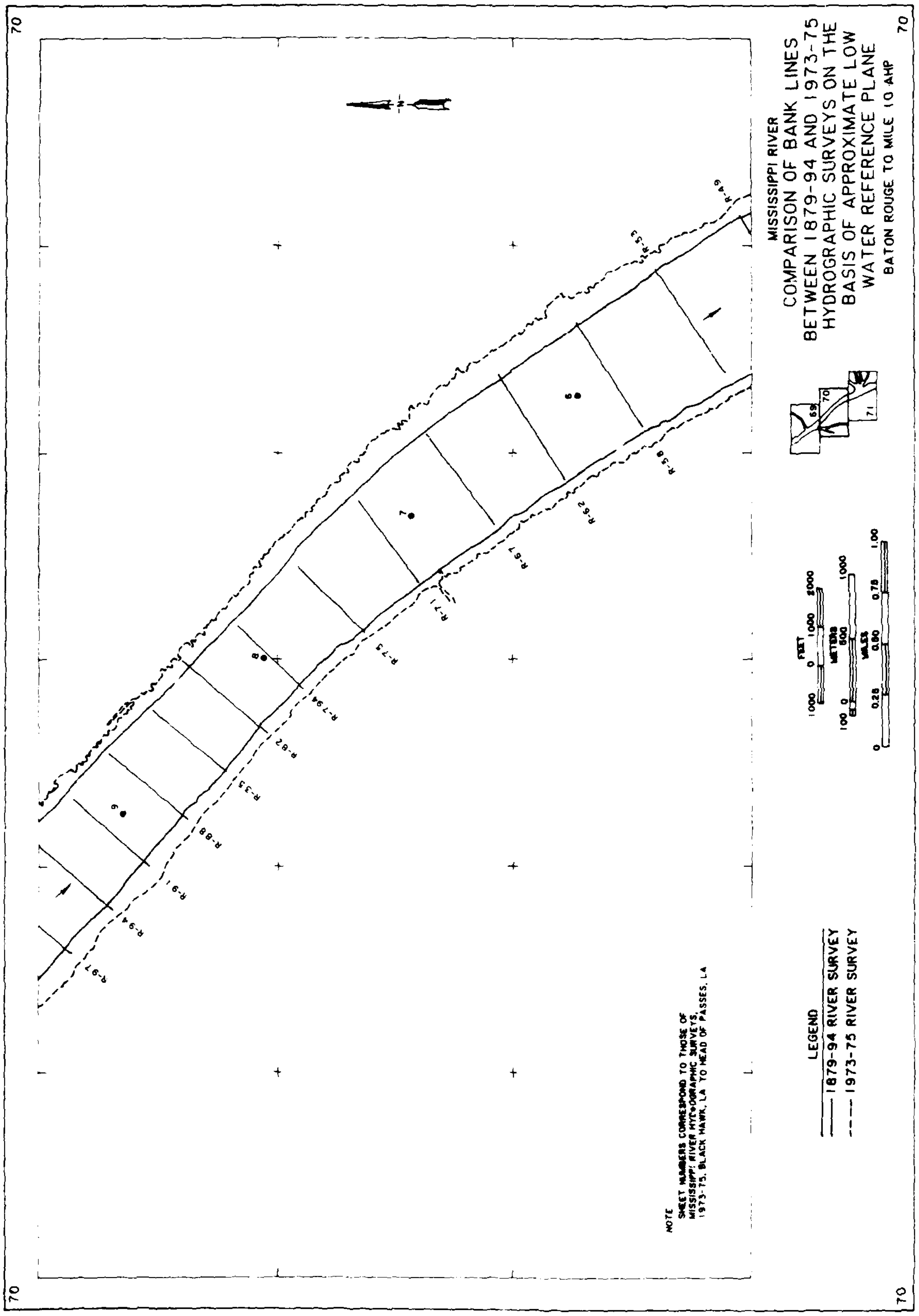
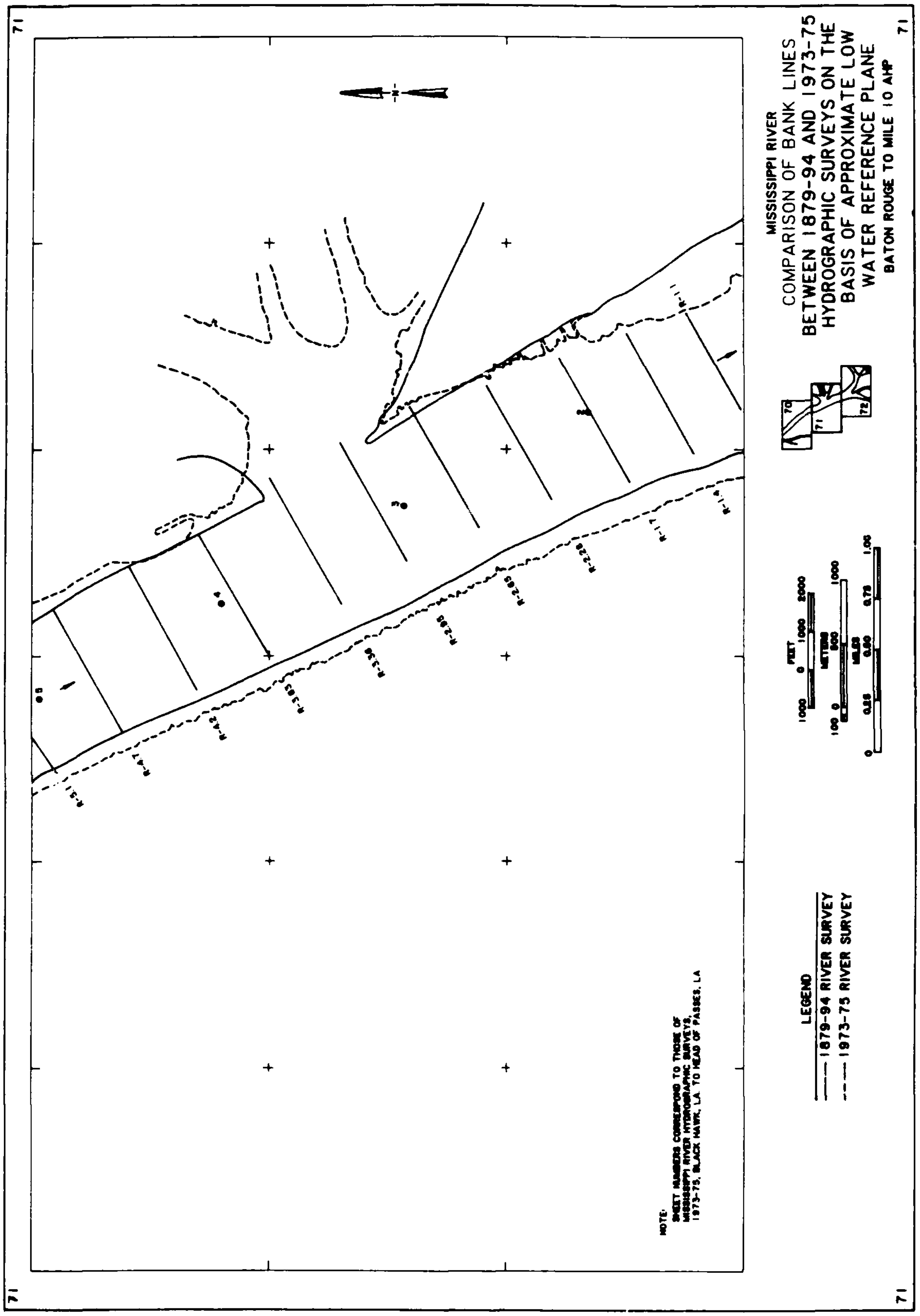
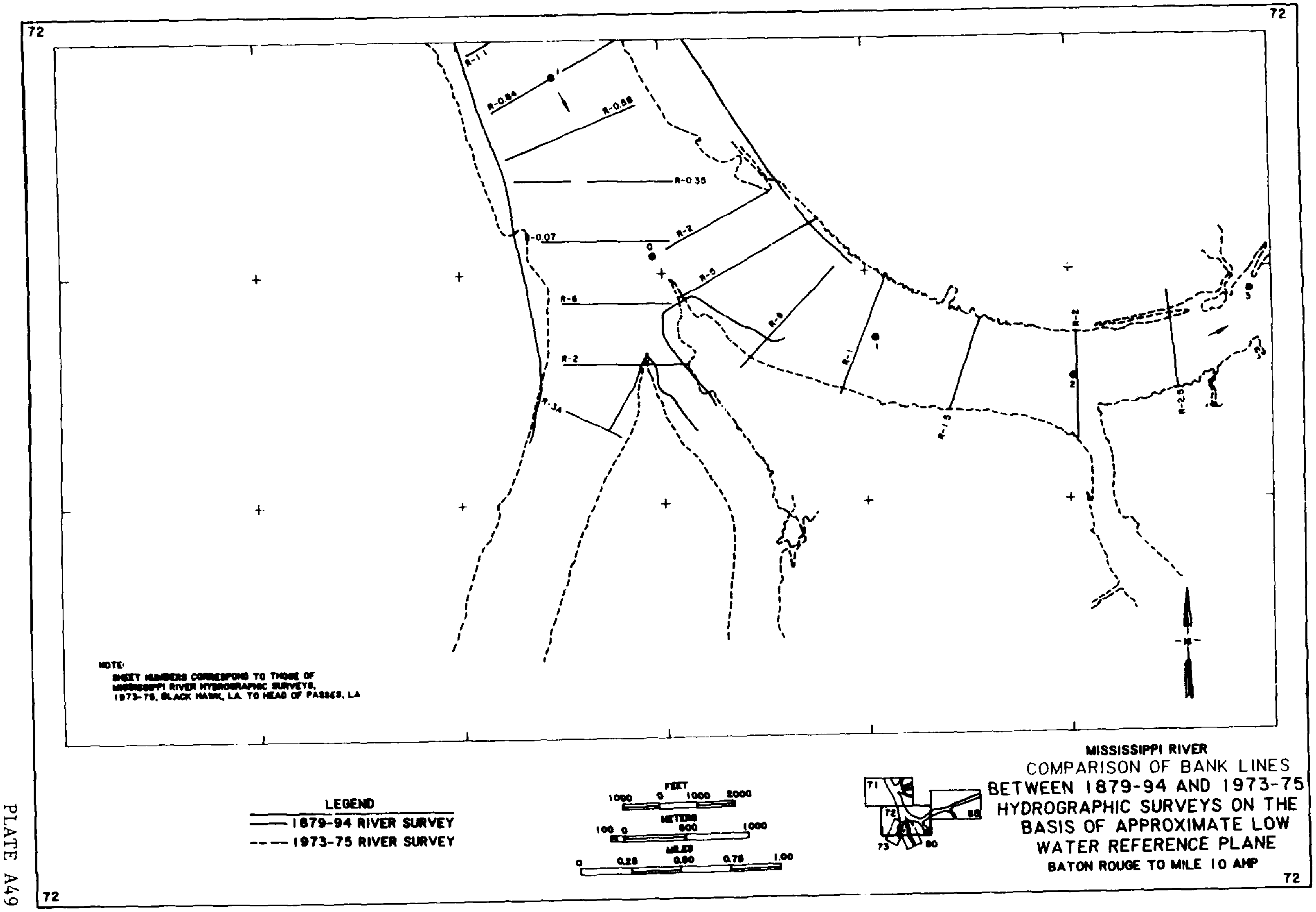

70
MISSISSIPPI RIVER
COMPARISON OF BANK LINES BETWEEN 1879-94 AND 1973-75 HYDROGRAPHIC SURVEYS ON THE BASIS OF APPROXIMATE LOW WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
FEET 1000 0 1000 2000
METERS 100 0 500 1000
MILES 0 0.25 0.50 0.75 1.00
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA

PLATE A47



71
MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP
FEET
1000 0 1000 2000
METERS
100 0 500 1000
MILES
0 0.25 0.50 0.75 1.00
LEGEND
1879-94 RIVER SURVEY
1973-75 RIVER SURVEY
NOTE:
SHEET NUMBERS CORRESPOND TO THOSE OF MISSISSIPPI RIVER HYDROGRAPHIC SURVEYS, 1973-75, BLACK HAWK, LA TO HEAD OF PASSES, LA

PLATE A48

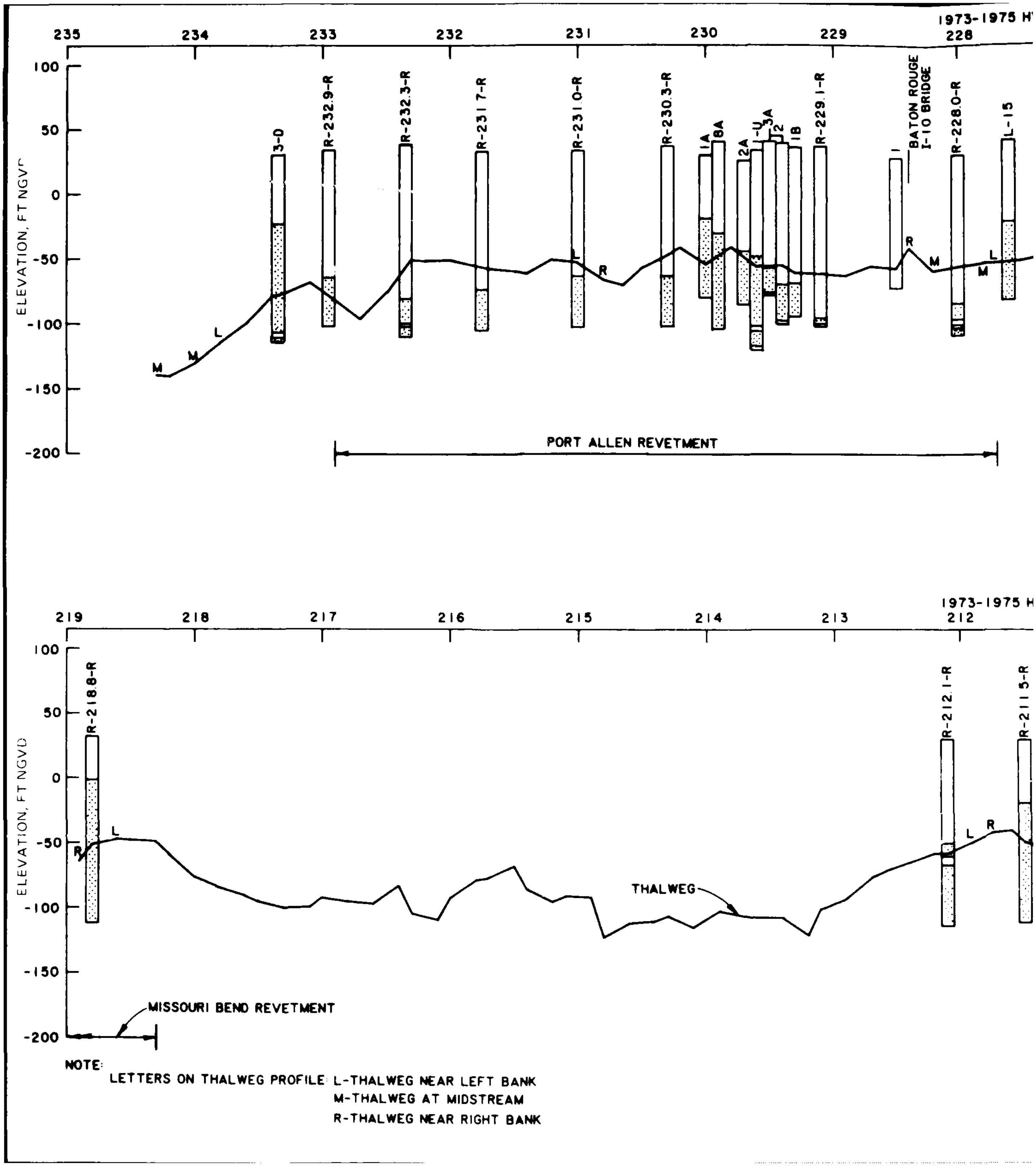


MISSISSIPPI RIVER
COMPARISON OF BANK LINES
BETWEEN 1879-94 AND 1973-75
HYDROGRAPHIC SURVEYS ON THE
BASIS OF APPROXIMATE LOW
WATER REFERENCE PLANE
BATON ROUGE TO MILE 10 AHP

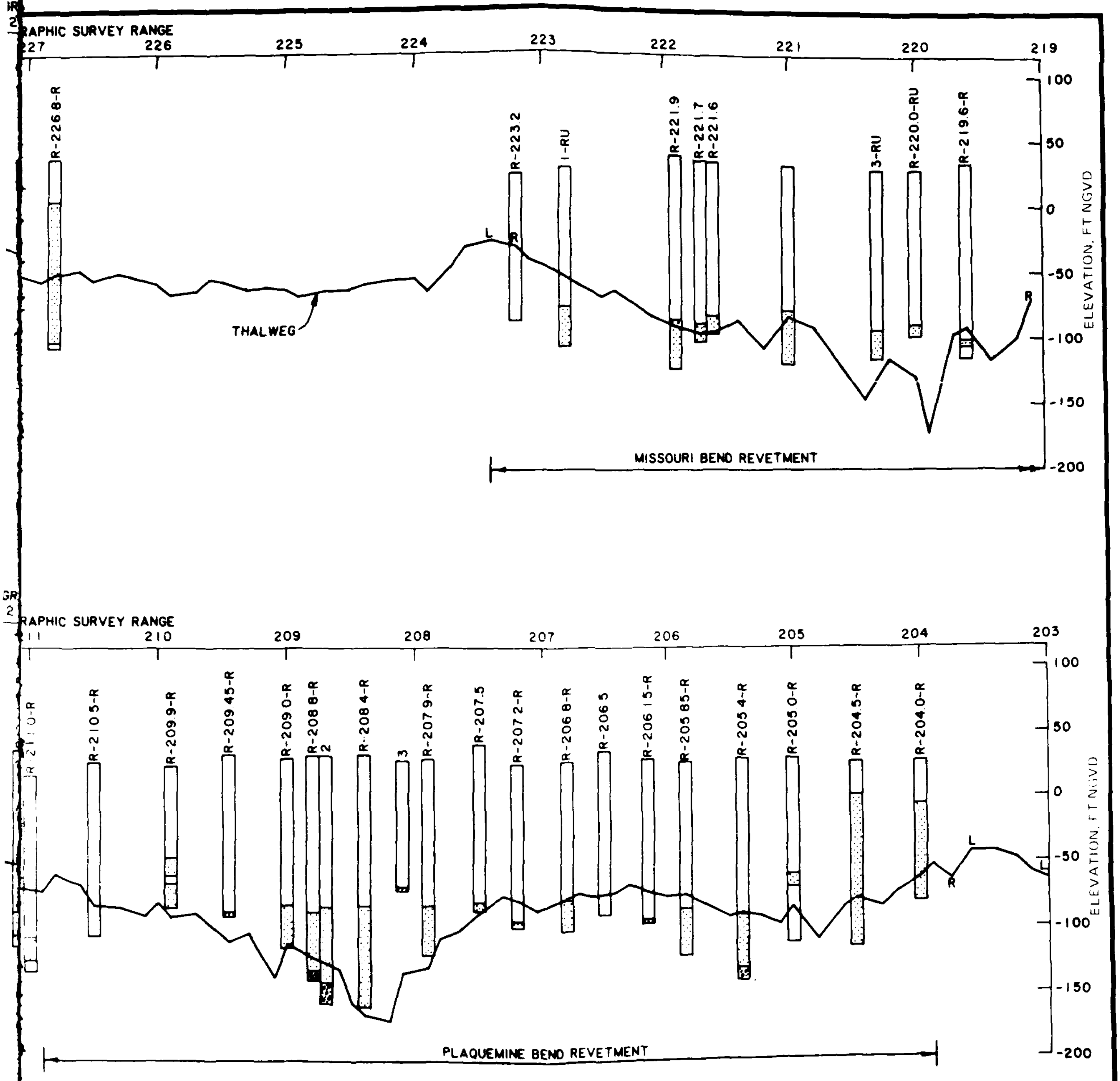
PLATE A49

APPENDIX B

COMPILATION OF PERTINENT BORING DATA BELOW BATON ROUGE, LA



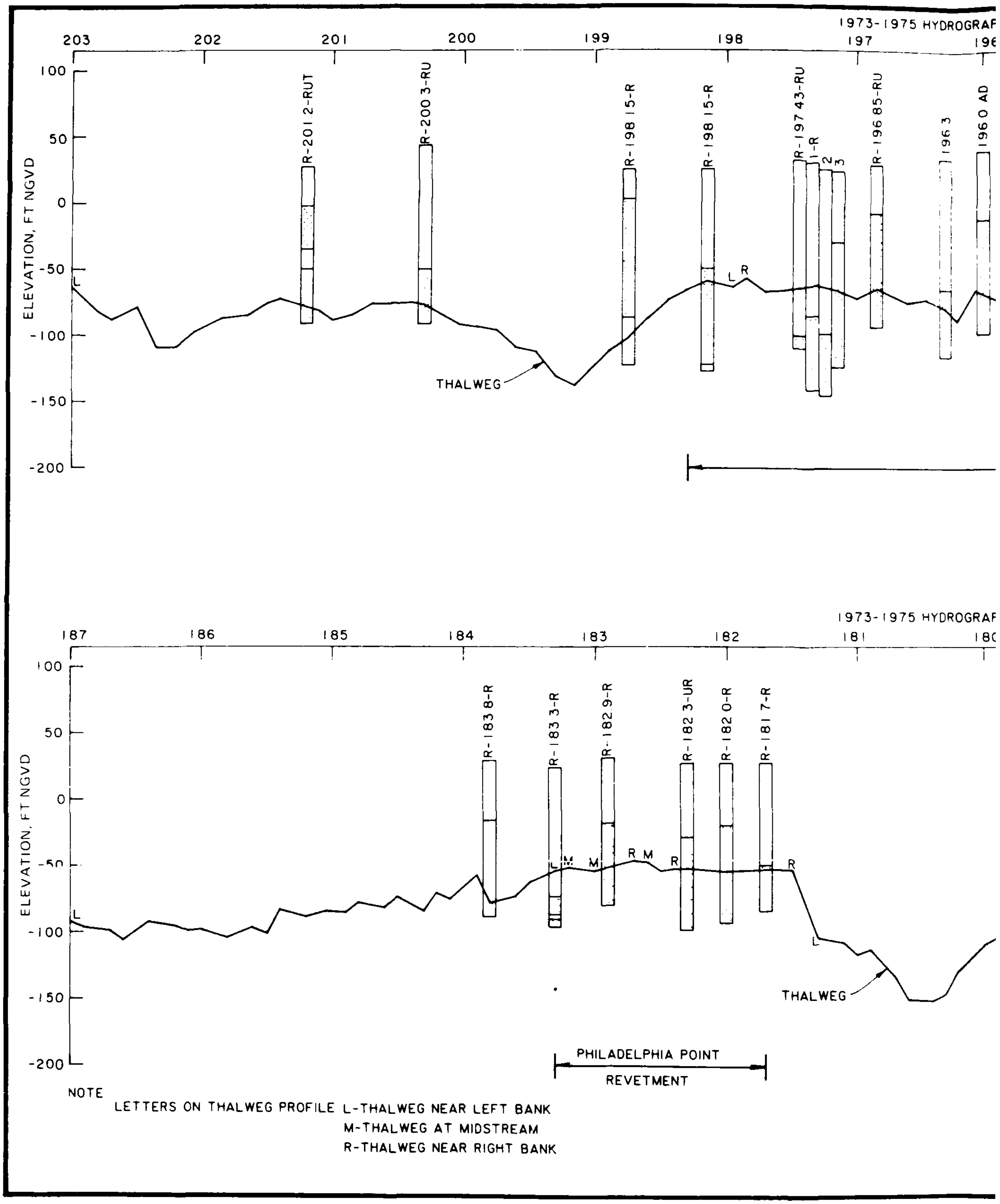
1973-1975 H
235
234
233
232
231
230
229
228
ELEVATION, FT NGVD
100
50
0
-50
-100
-150
-200
3-D
R-232.9-R
R-232.3-R
R-231.7-R
R-231.0-R
R-230.3-R
1A
8A
2A
1-U
3A
2
1B
R-229.1-R
1
BATON ROUGE I-10 BRIDGE
R-228.0-R
L-15
M
L
R
PORT ALLEN REVETMENT
1973-1975 H
219
218
217
216
215
214
213
212
R-218.8-R
R-212.1-R
R-211.5-R
THALWEG
MISSOURI BEND REVETMENT
NOTE:
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK



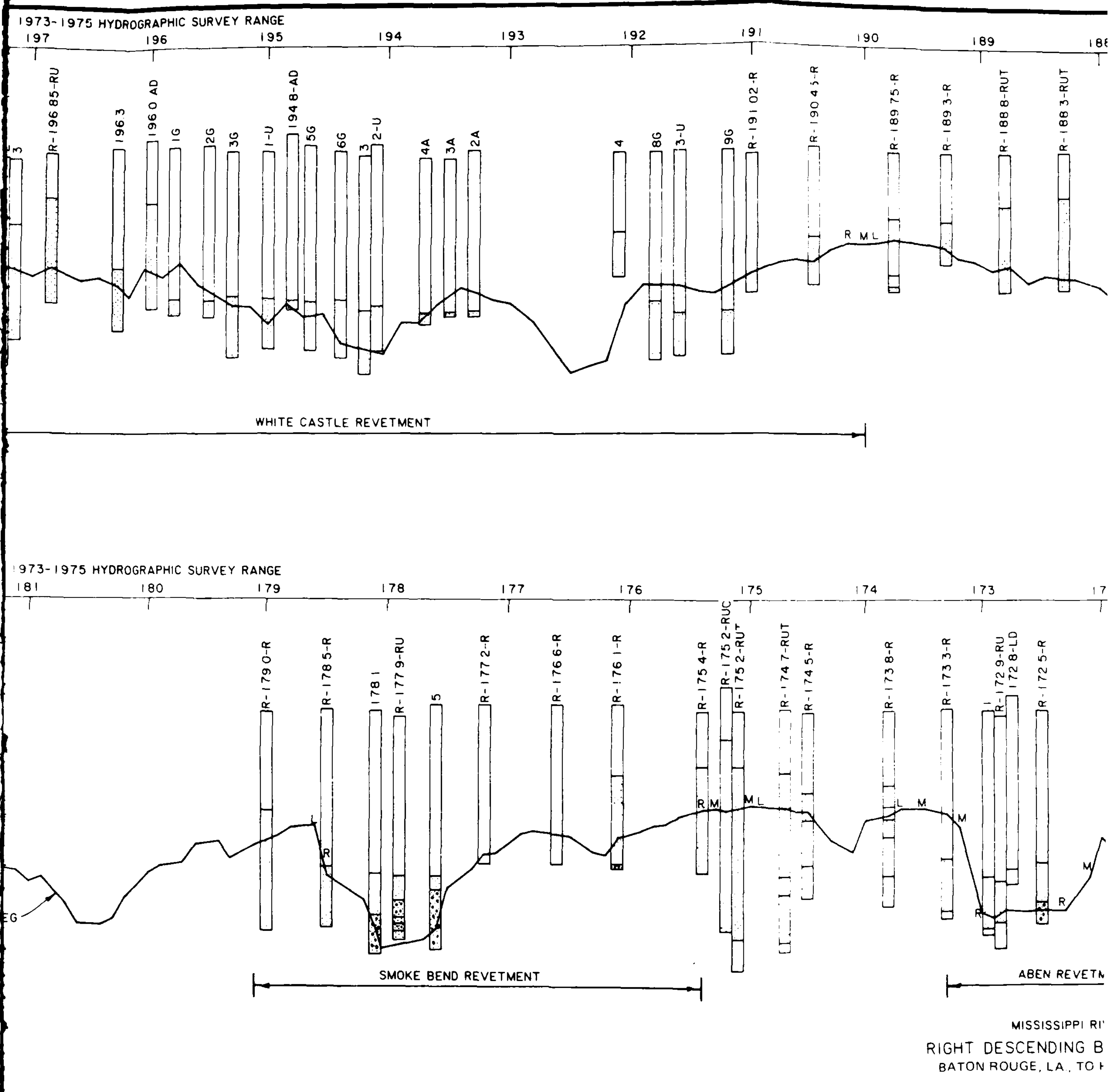
MISSISSIPPI RIVER

RIGHT DESCENDING BANK BORINGS

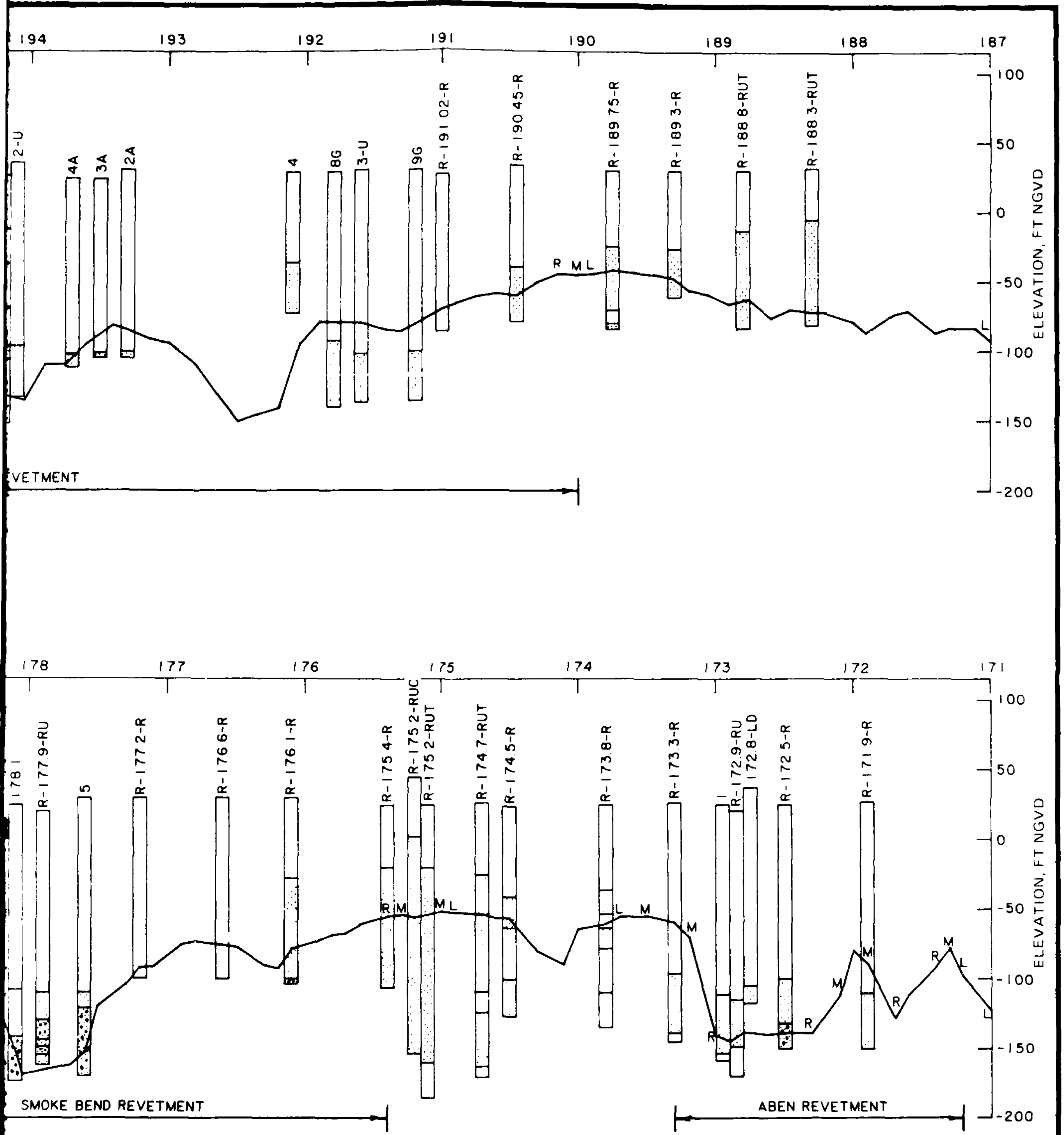
BATON ROUGE, LA., TO HEAD OF PASSES



1973-1975 HYDROGRAP
203
202
201
200
199
198
197
196
ELEVATION, FT NGVD
100
50
0
-50
-100
-150
-200
R-201 2-RUT
R-200 3-RU
R-198 15-R
R-198 15-R
R-197 43-RU
1-R
2
3
R-196 85-RU
196 3
196 0 AD
L
L
R
THALWEG
1973-1975 HYDROGRAP
187
186
185
184
183
182
181
180
R-183 8-R
R-183 3-R
R-182 9-R
R-182 3-UR
R-182 0-R
R-181 7-R
L
M
M
R
M
R
R
L
THALWEG
PHILADELPHIA POINT
REVETMENT
NOTE
LETTERS ON THALWEG PROFILE L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK



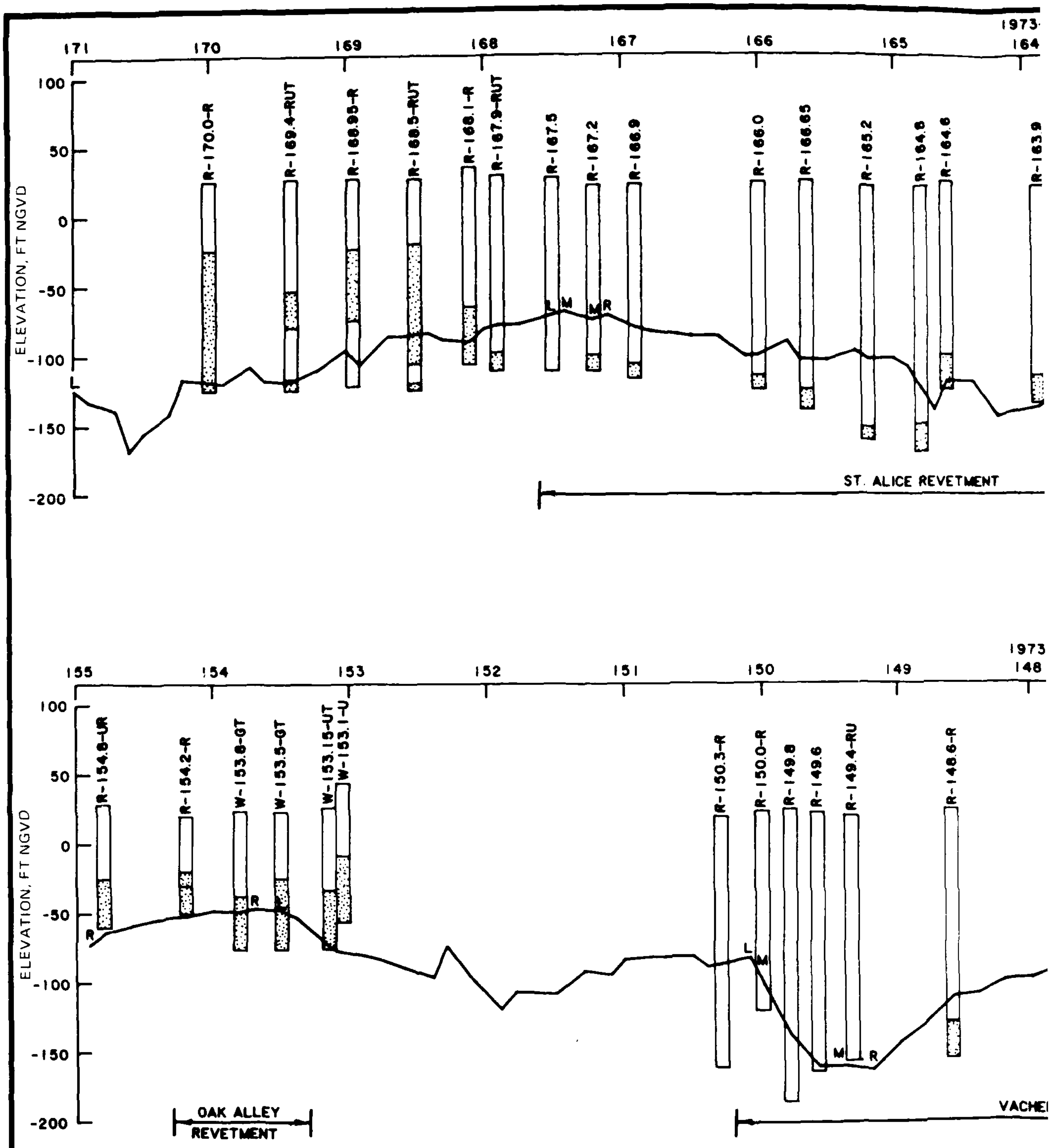
1973-1975 HYDROGRAPHIC SURVEY RANGE
197
196
195
194
193
192
191
190
189
R-19685-RU
1963
1960 AD
1948-AD
R-19102-R
R-18975-R
R-1893-R
R-1888-RUT
R-1883-RUT
WHITE CASTLE REVETMENT
1973-1975 HYDROGRAPHIC SURVEY RANGE
181
180
179
178
177
176
175
174
173
R-1790-R
R-1785-R
1781
R-1779-RU
R-1772-R
R-1766-R
R-1761-R
R-1754-R
R-1752-RUC
R-1752-RUT
R-1747-RUT
R-1745-R
R-1738-R
R-1733-R
R-1729-RU
1728-LD
R-1725-R
SMOKE BEND REVETMENT
ABEN REVETM
MISSISSIPPI RI
RIGHT DESCENDING B
BATON ROUGE, LA., TO



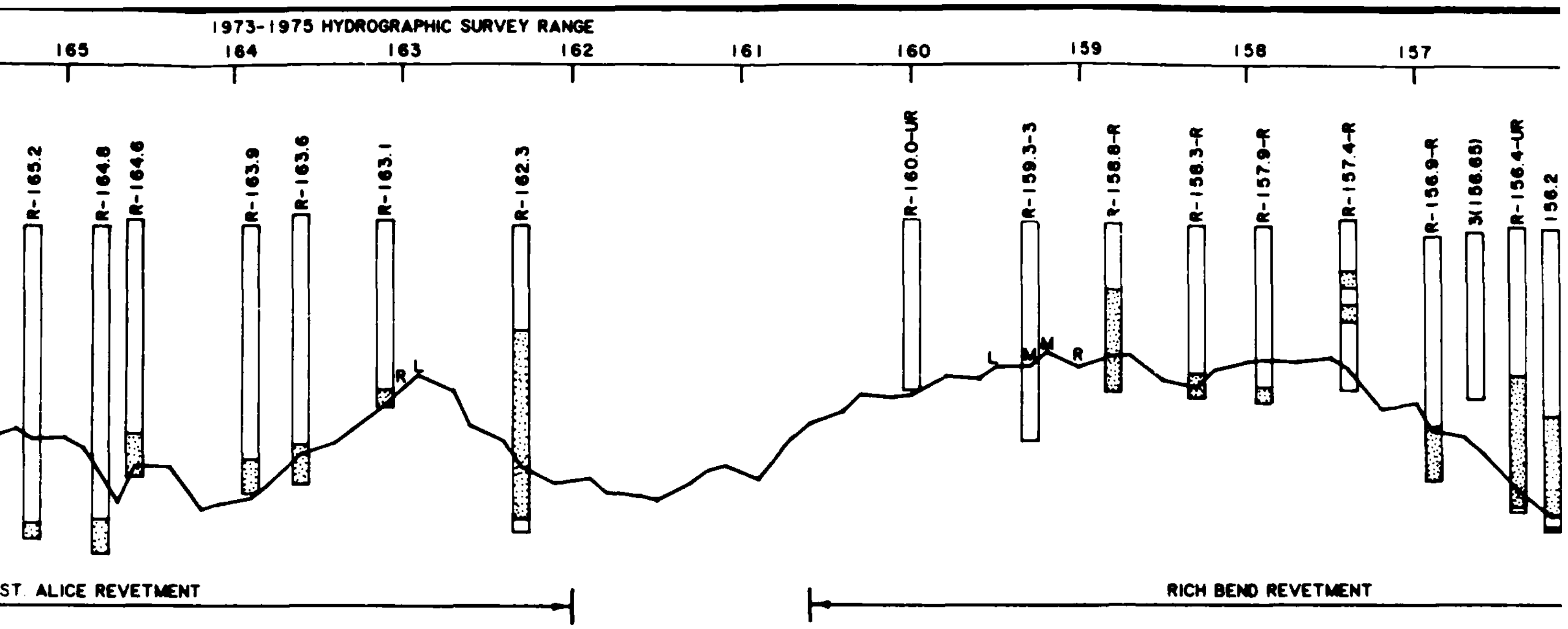
MISSISSIPPI RIVER

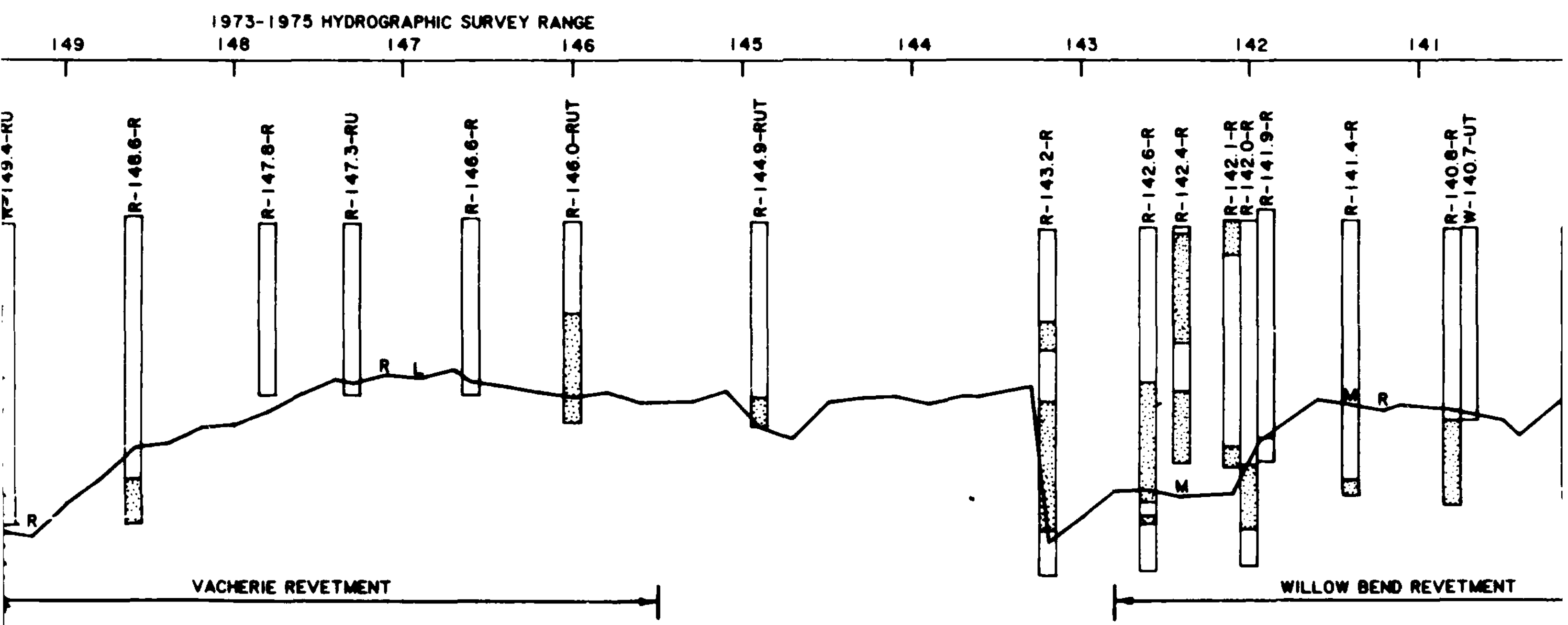
RIGHT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES



NOTE:
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK

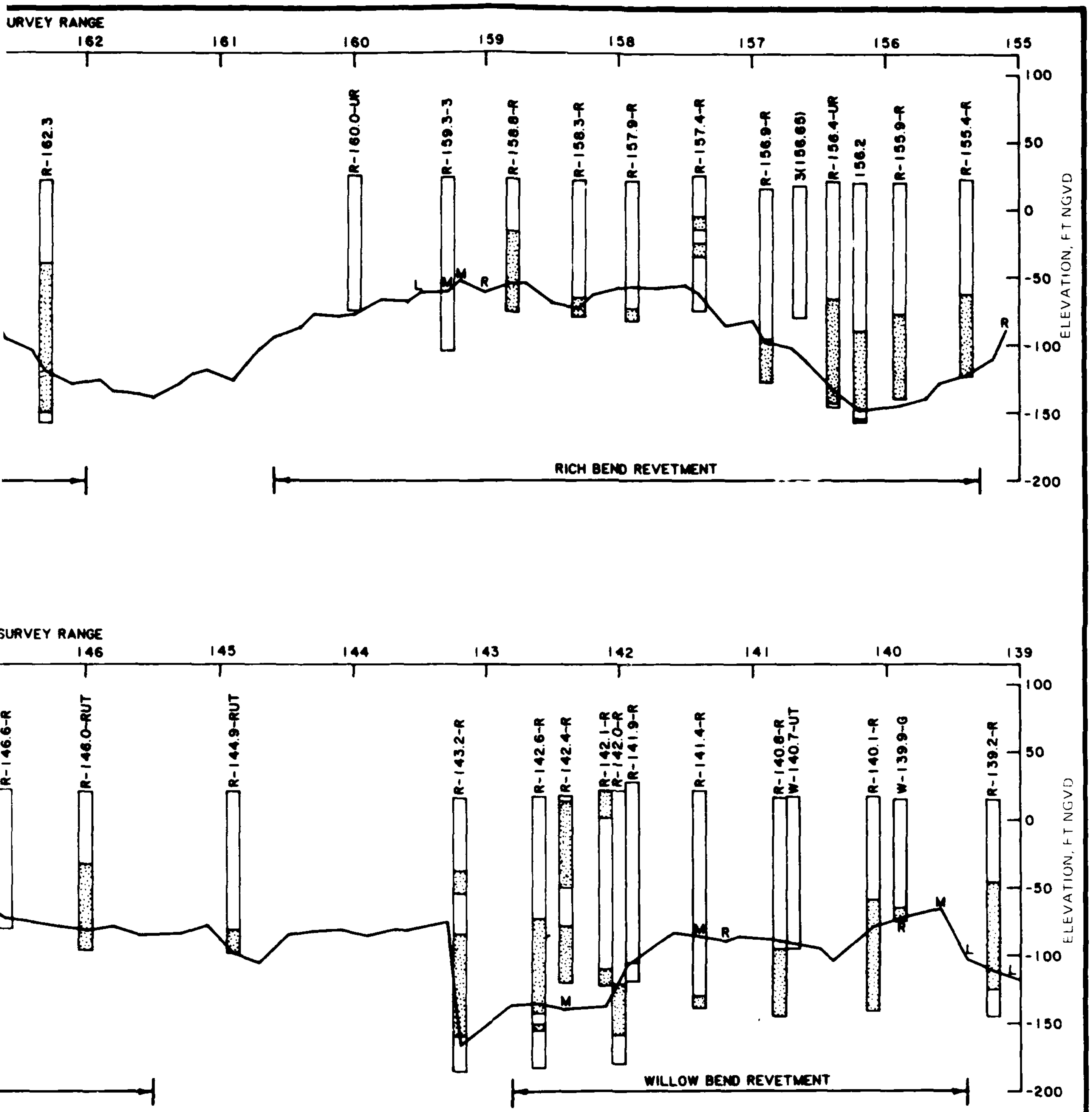




MISSISSIPP

RIGHT DESCENDING

BATON ROUGE, LA., T

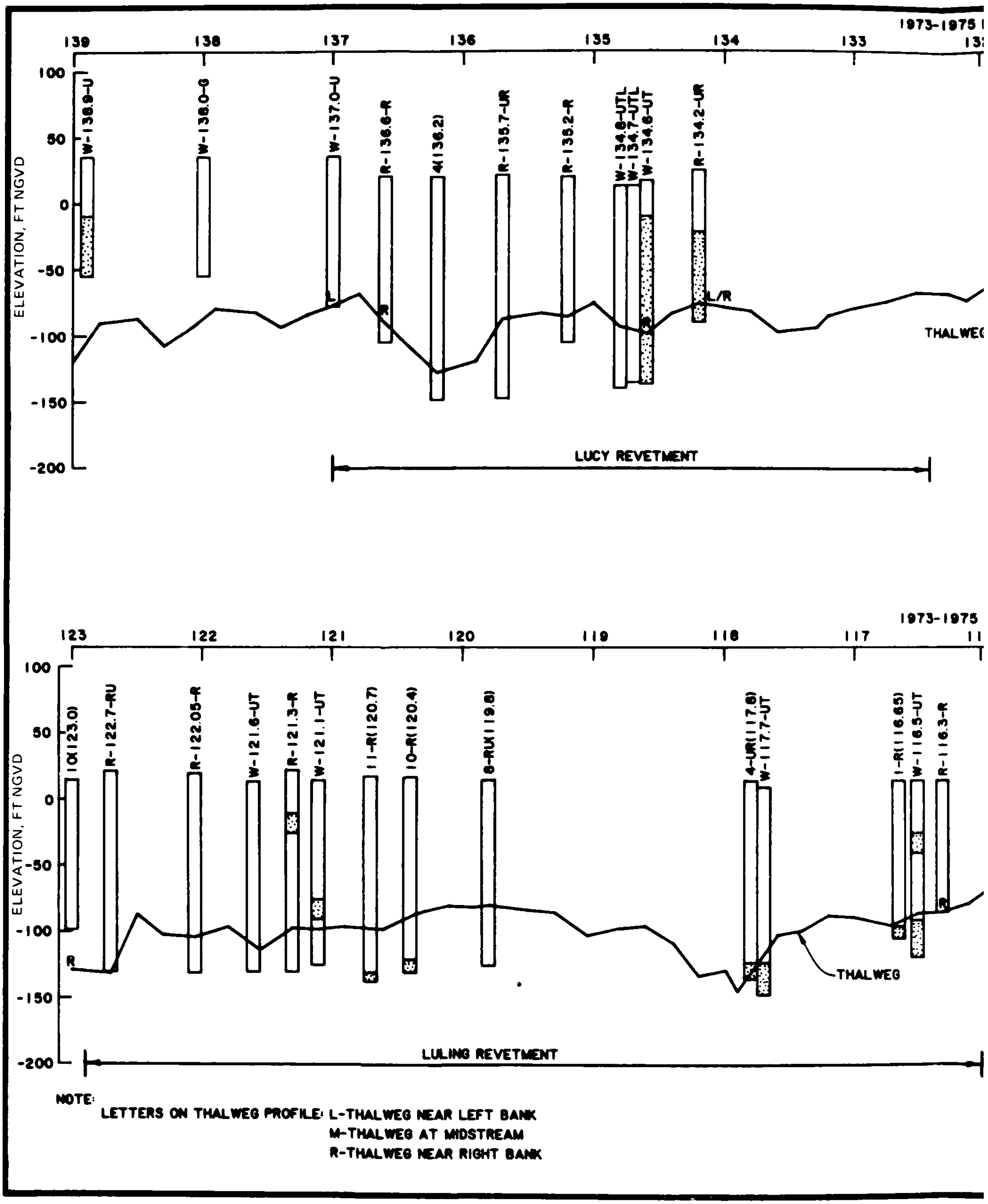


MISSISSIPPI RIVER

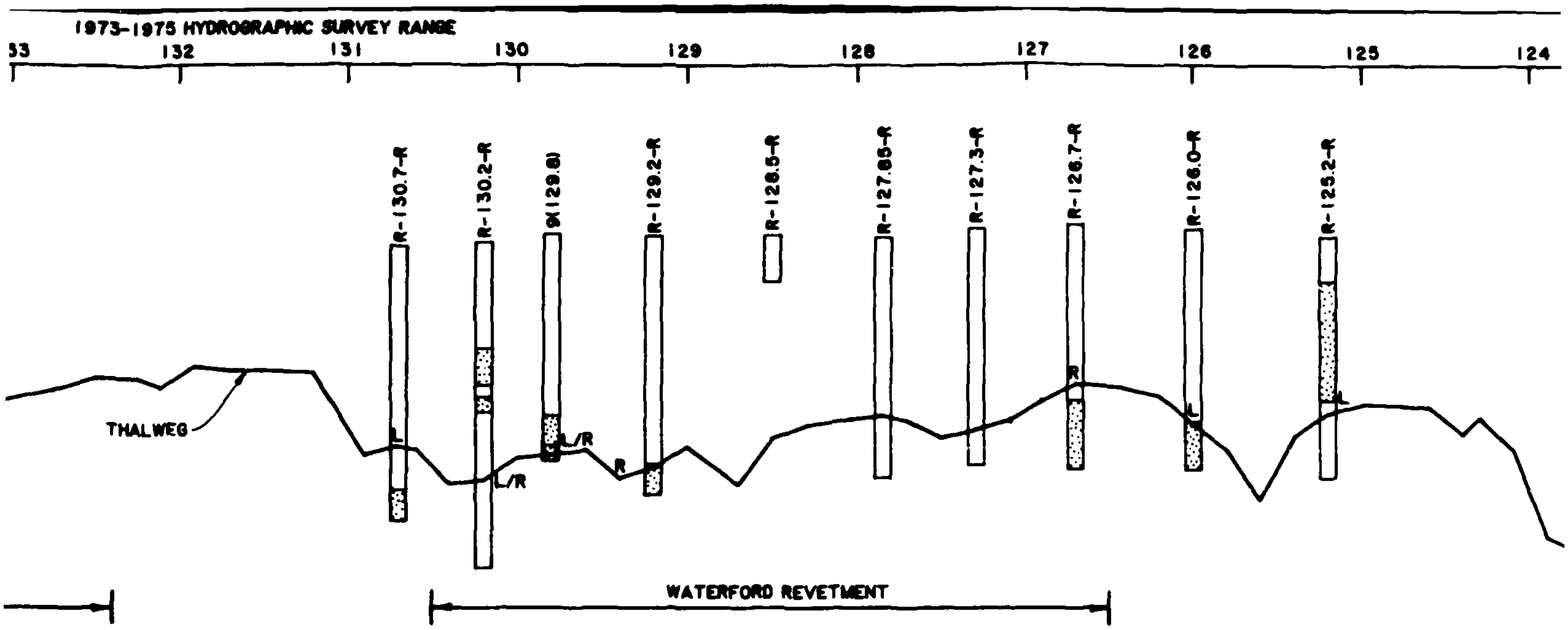
RIGHT DESCENDING BANK BORINGS

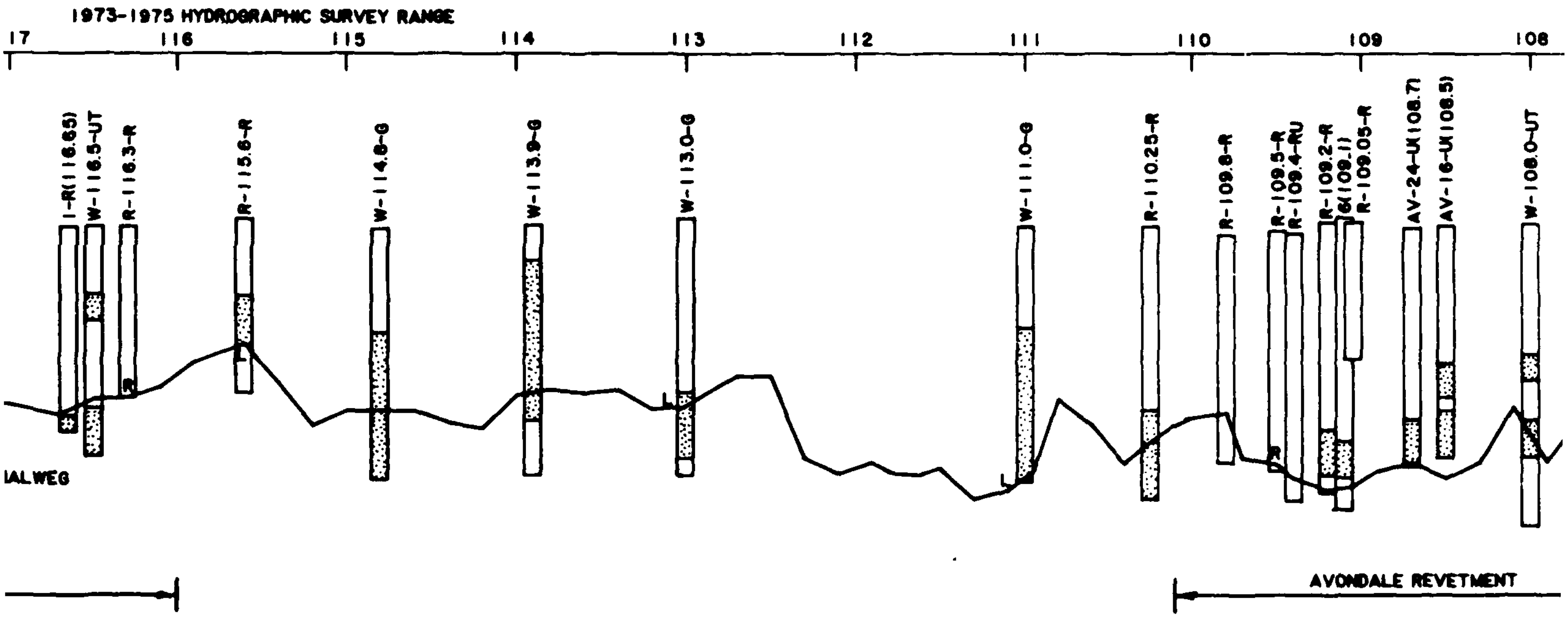
BATON ROUGE, LA., TO HEAD OF PASSES

2 3



ELEVATION, FT NGVD
W-138.9-U
W-138.0-G
W-137.0-U
R-136.6-R
4(136.2)
R-135.7-UR
R-135.2-R
W-134.8-UTL
W-134.7-UTL
W-134.6-UT
R-134.2-UR
L/R
THALWEG
LUCY REVETMENT
1973-1975
10(123.0)
R-122.7-RU
R-122.05-R
W-121.6-UT
R-121.3-R
W-121.1-UT
11-R(120.7)
10-R(120.4)
8-RU(119.8)
4-UR(117.8)
W-117.7-UT
1-R(116.65)
W-116.5-UT
R-116.3-R
THALWEG
LULING REVETMENT
NOTE:
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK



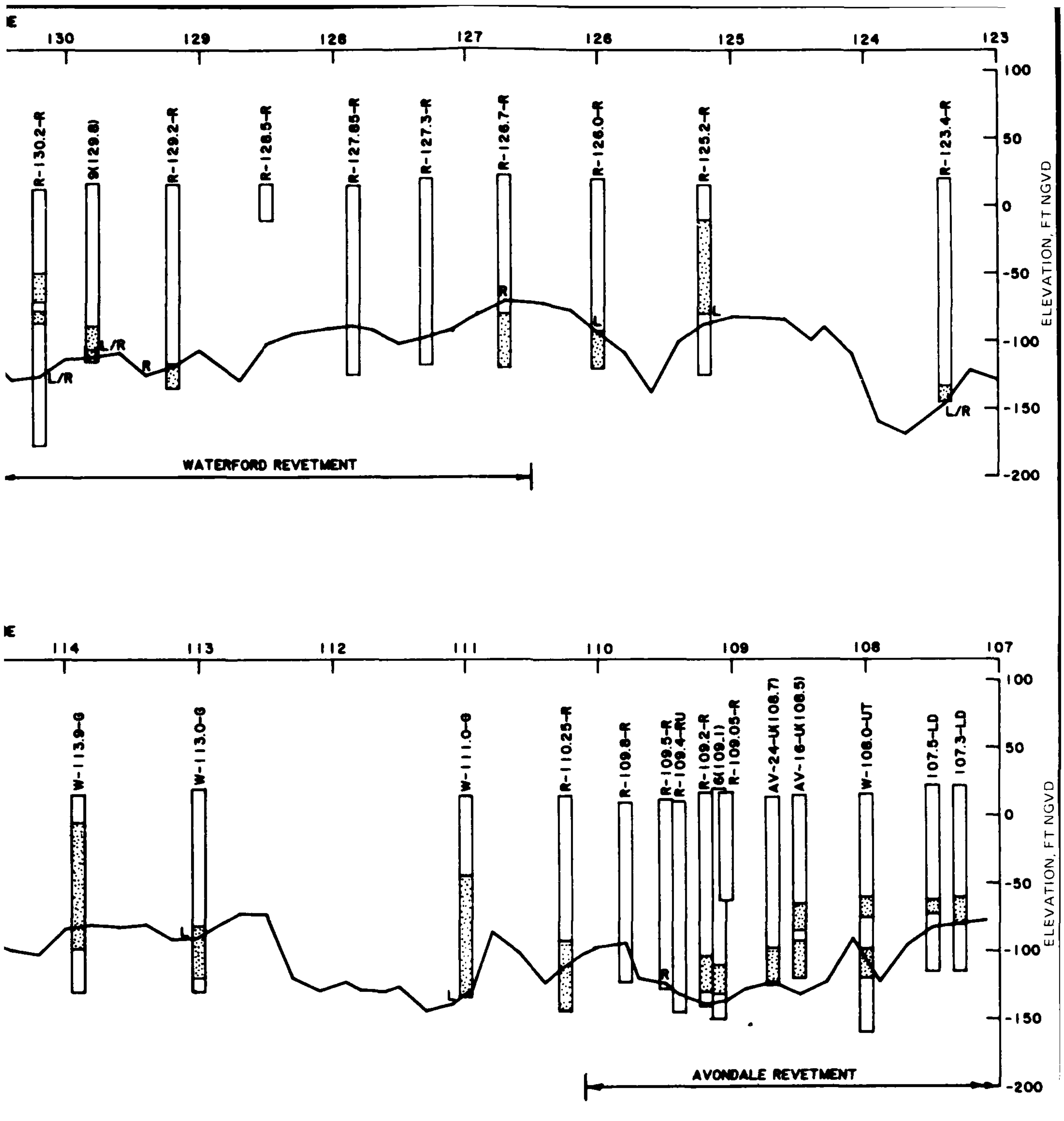


MISSISSIPPI RIVEI

RIGHT DESCENDING BAI

BATON ROUGE, LA., TO HEA

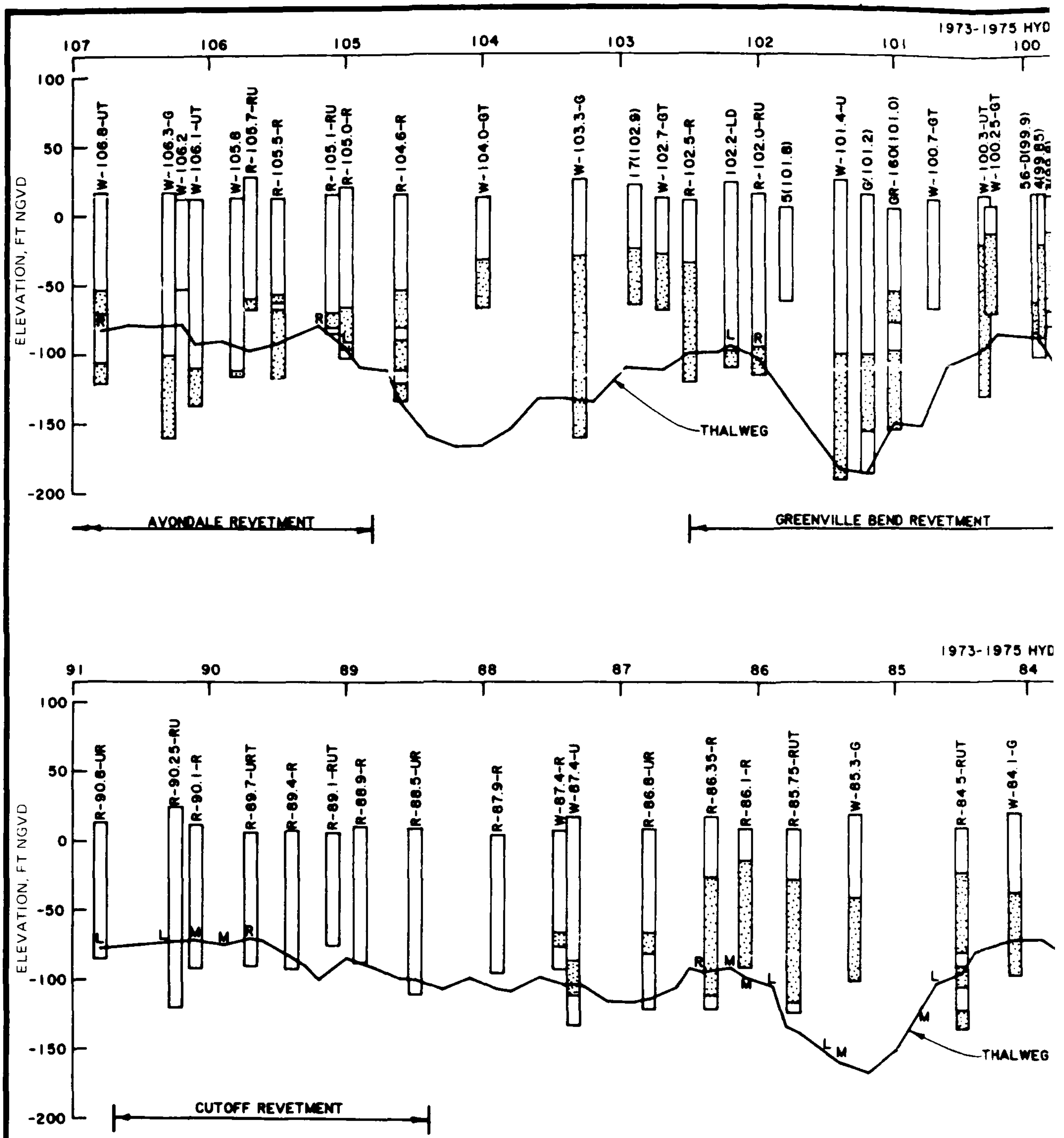
2



MISSISSIPPI RIVER

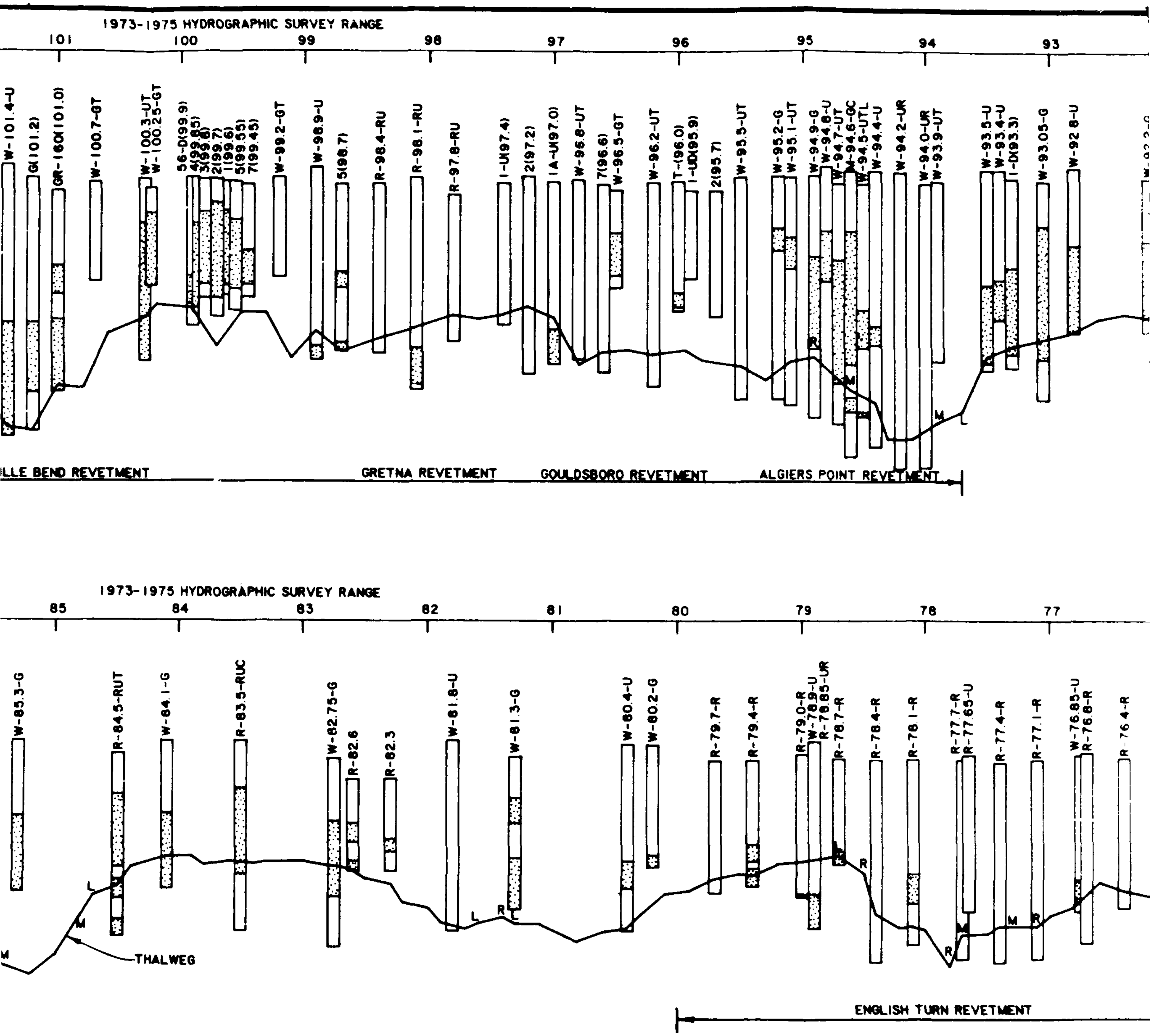
RIGHT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES



NOTE:

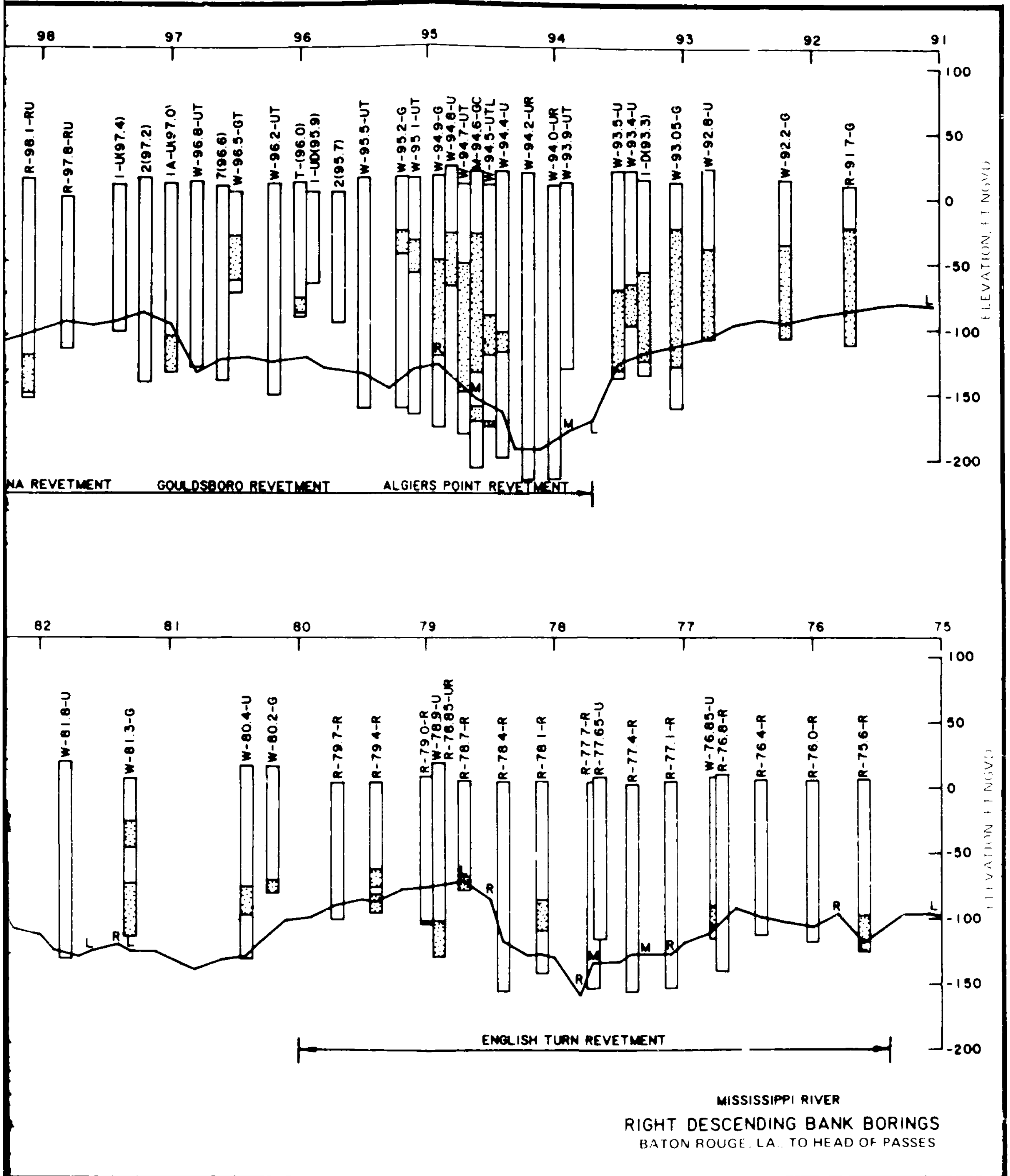
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK



MISSISSIPP

RIGHT DESCENDIN

BATON ROUGE, LA

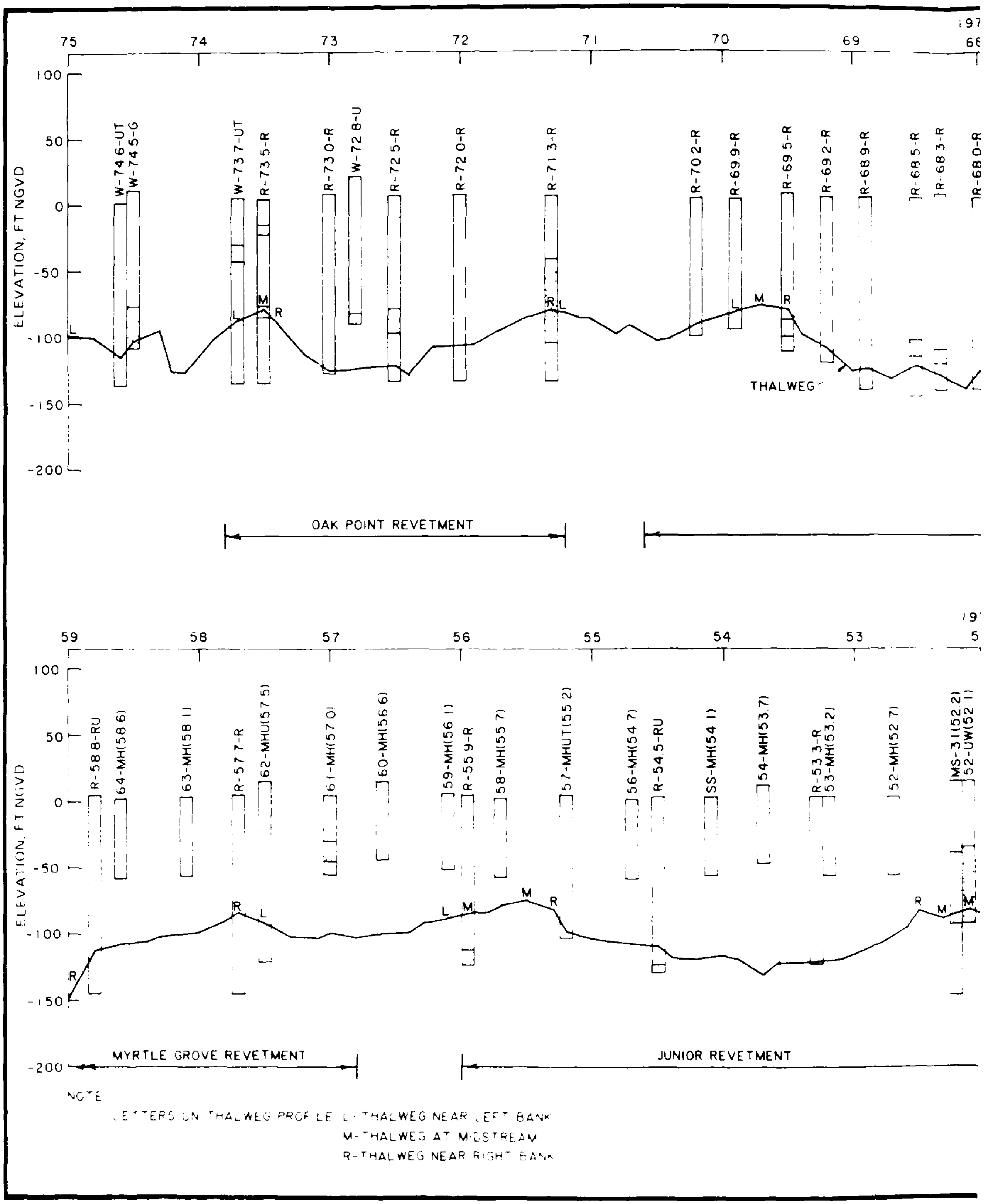


MISSISSIPPI RIVER

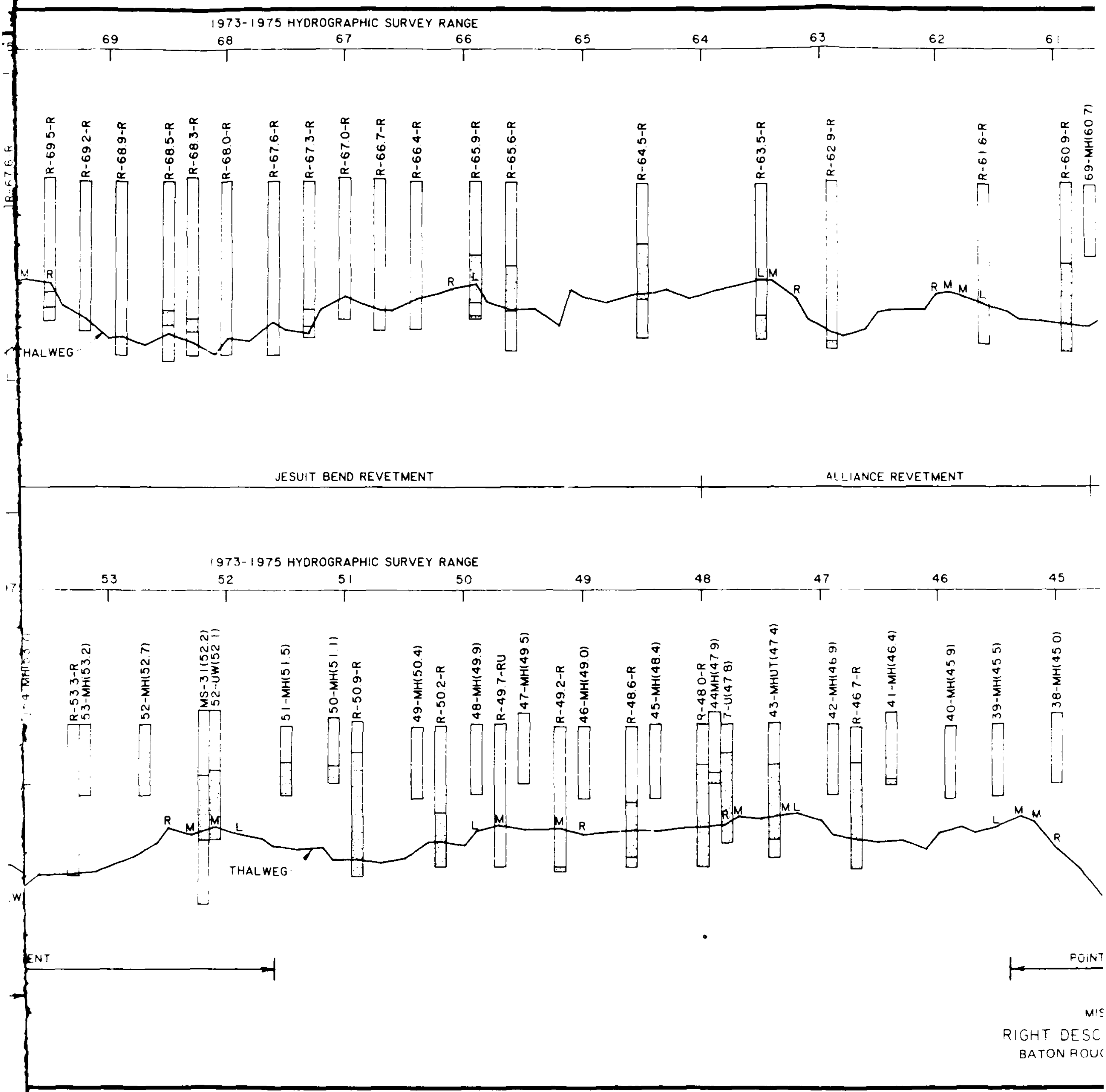
RIGHT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES

PLATE B5

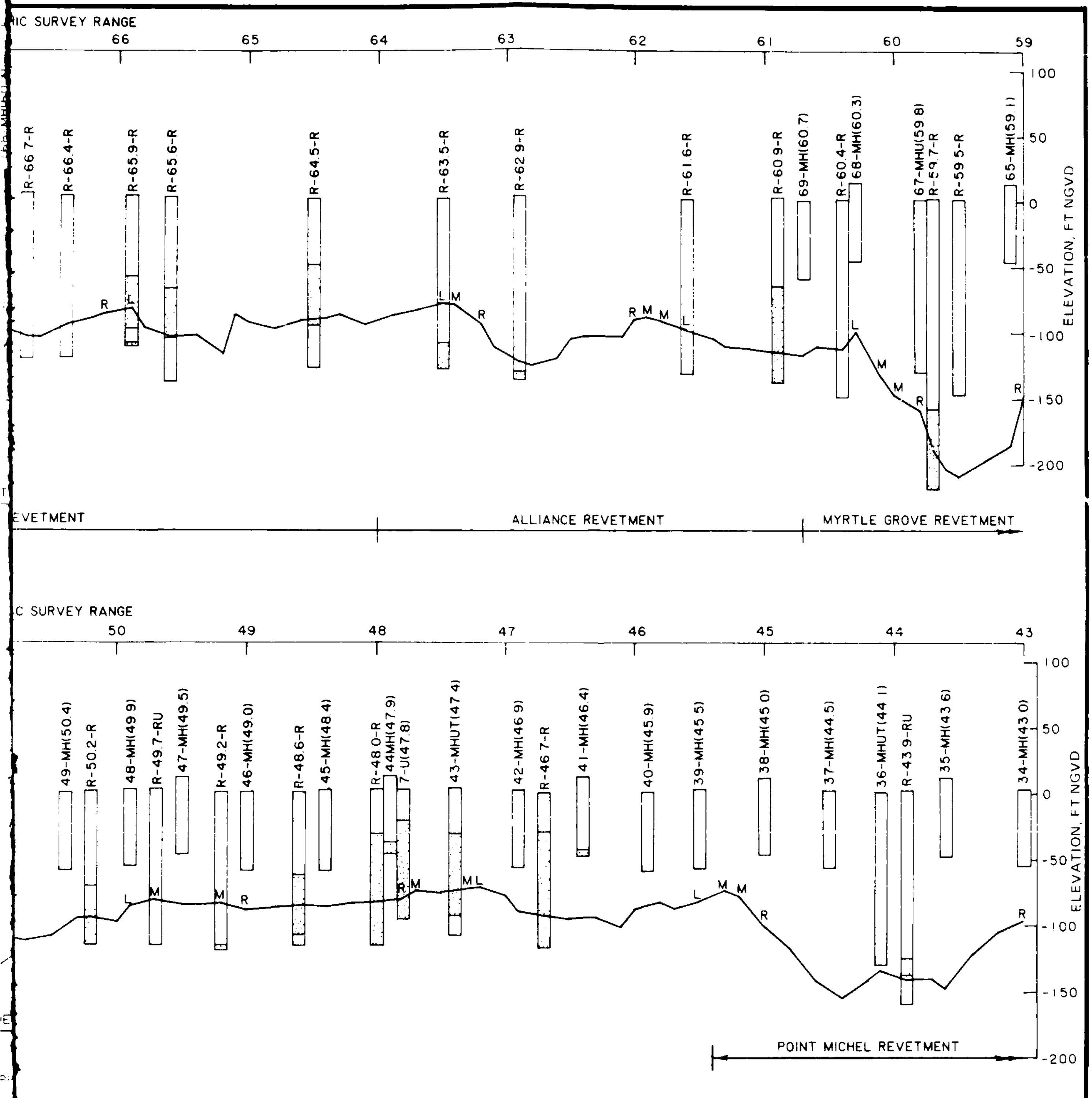


ELEVATION, FT NGVD
THALWEG
OAK POINT REVETMENT
MYRTLE GROVE REVETMENT
JUNIOR REVETMENT
W-746-UT
W-745-G
W-737-UT
R-735-R
R-730-R
W-728-U
R-725-R
R-720-R
R-713-R
R-702-R
R-699-R
R-695-R
R-692-R
R-689-R
R-685-R
R-683-R
R-680-R
R-588-RU
64-MH(58 6)
63-MH(58 1)
R-577-R
62-MHU(57 5)
61-MH(57 0)
60-MH(56 6)
59-MH(56 1)
R-559-R
58-MH(55 7)
57-MHUT(55 2)
56-MH(54 7)
R-54.5-RU
55-MH(54 1)
54-MH(53 7)
R-53 3-R
53-MH(53.2)
52-MH(52 7)
MS-31(52 2)
52-UW(52 1)
NOTE
LETTERS ON THALWEG PROFILE L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK


1973-1975 HYDROGRAPHIC SURVEY RANGE
69
68
67
66
65
64
63
62
61
R-69.5-R
R-69.2-R
R-68.9-R
R-68.5-R
R-68.3-R
R-68.0-R
R-67.6-R
R-67.3-R
R-67.0-R
R-66.7-R
R-66.4-R
R-65.9-R
R-65.6-R
R-64.5-R
R-63.5-R
R-62.9-R
R-61.6-R
R-60.9-R
69-MH(60.7)
THALWEG
JESUIT BEND REVETMENT
ALLIANCE REVETMENT
1973-1975 HYDROGRAPHIC SURVEY RANGE
53
52
51
50
49
48
47
46
45
R-53.3-R
53-MH(53.2)
52-MH(52.7)
MS-31(52.2)
52-UW(52.1)
51-MH(51.5)
50-MH(51.1)
R-50.9-R
49-MH(50.4)
R-50.2-R
48-MH(49.9)
R-49.7-RU
47-MH(49.5)
R-49.2-R
46-MH(49.0)
R-48.6-R
45-MH(48.4)
R-48.0-R
44MH(47.9)
7-U(47.8)
43-MHUT(47.4)
42-MH(46.9)
R-46.7-R
41-MH(46.4)
40-MH(45.9)
39-MH(45.5)
38-MH(45.0)
THALWEG
ENT
POINT
MIS
RIGHT DESC
BATON ROUG

1

2



MISSISSIPPI RIVER

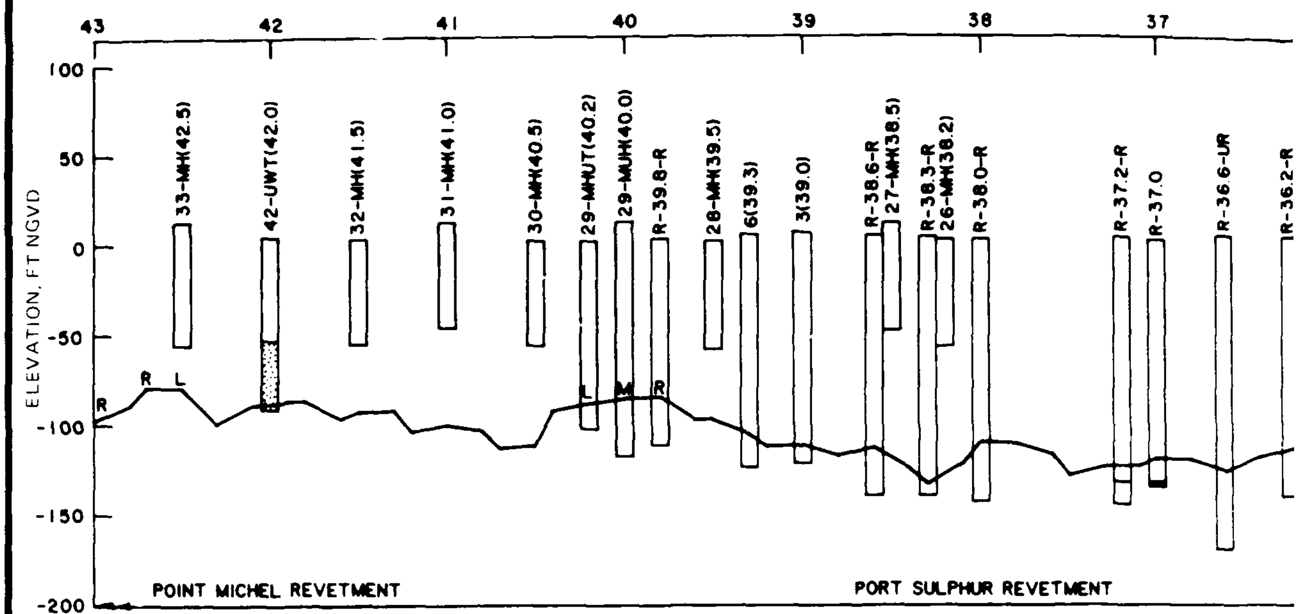
RIGHT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES

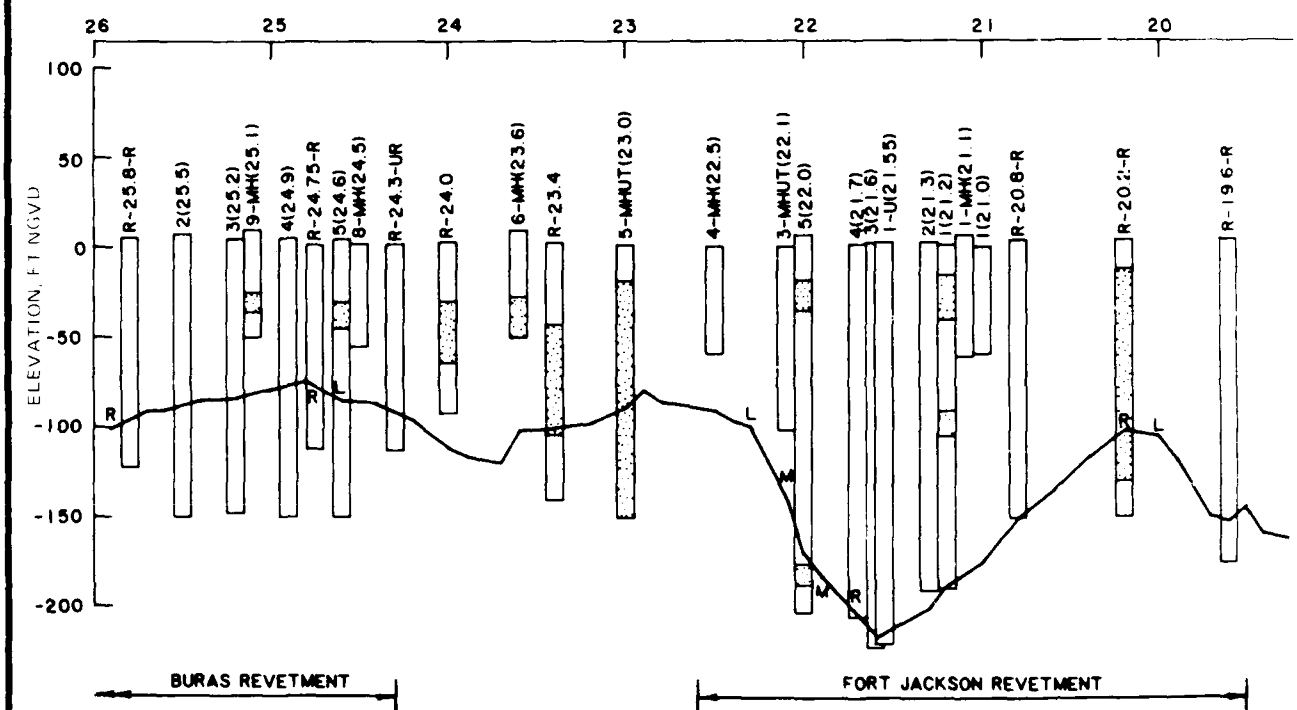
PLATE B6

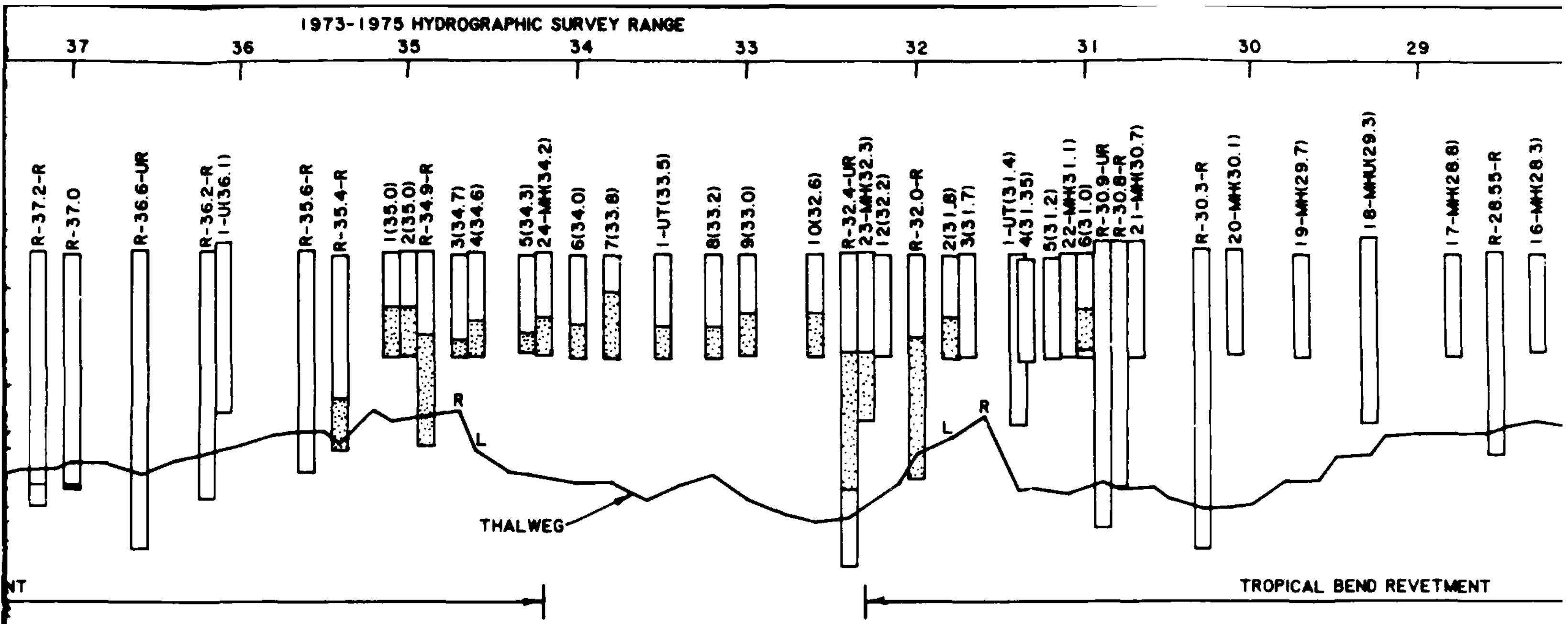
2

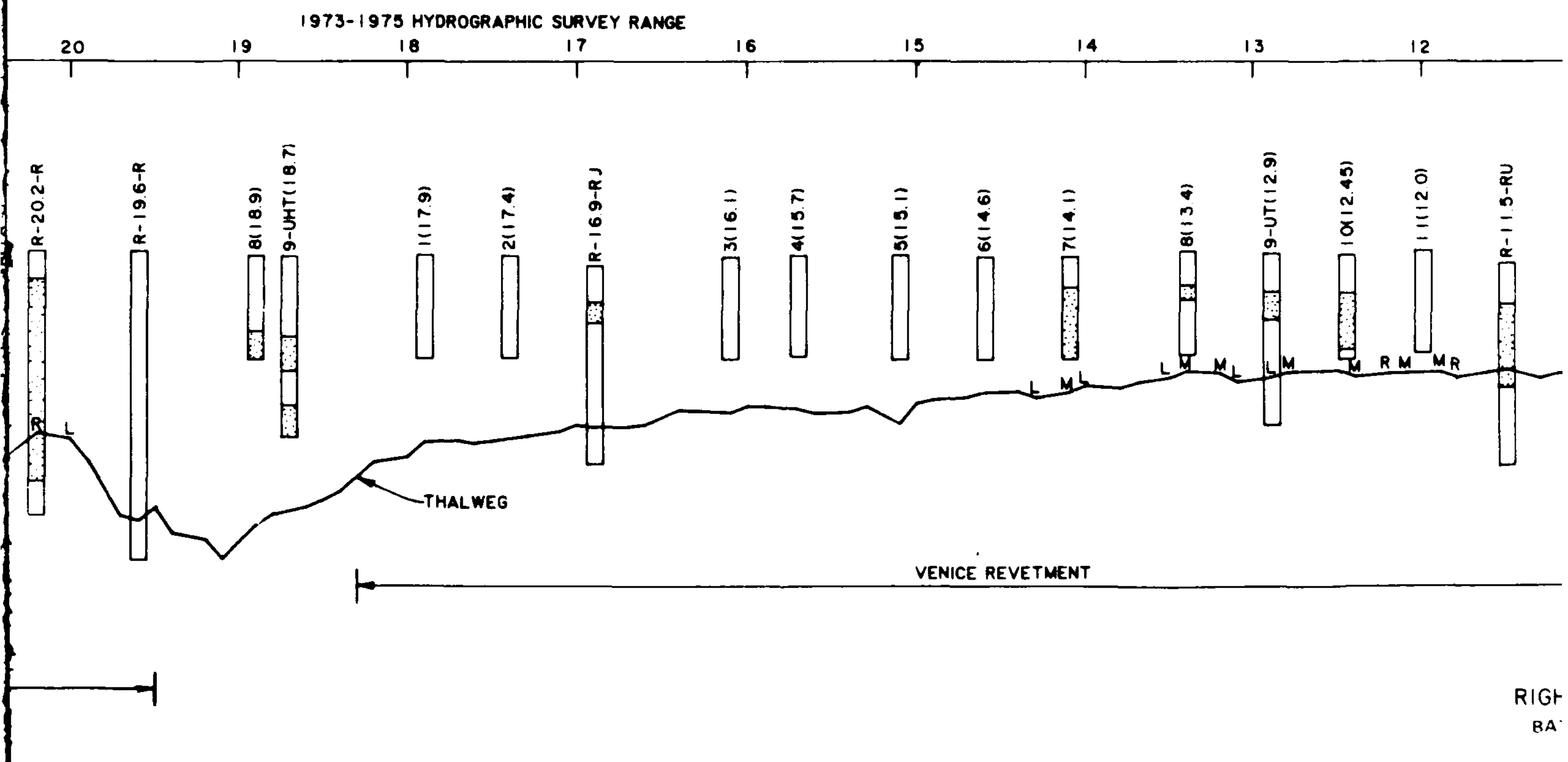
3



NOTE:
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK

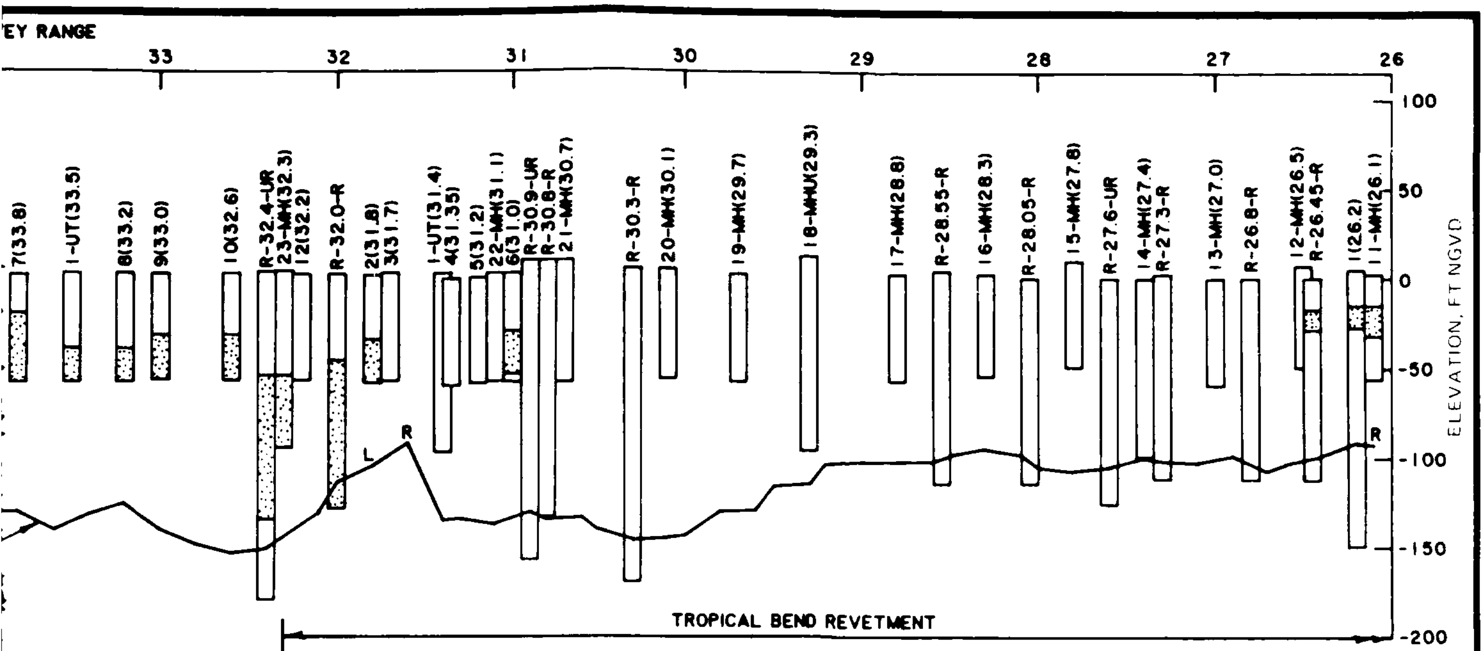


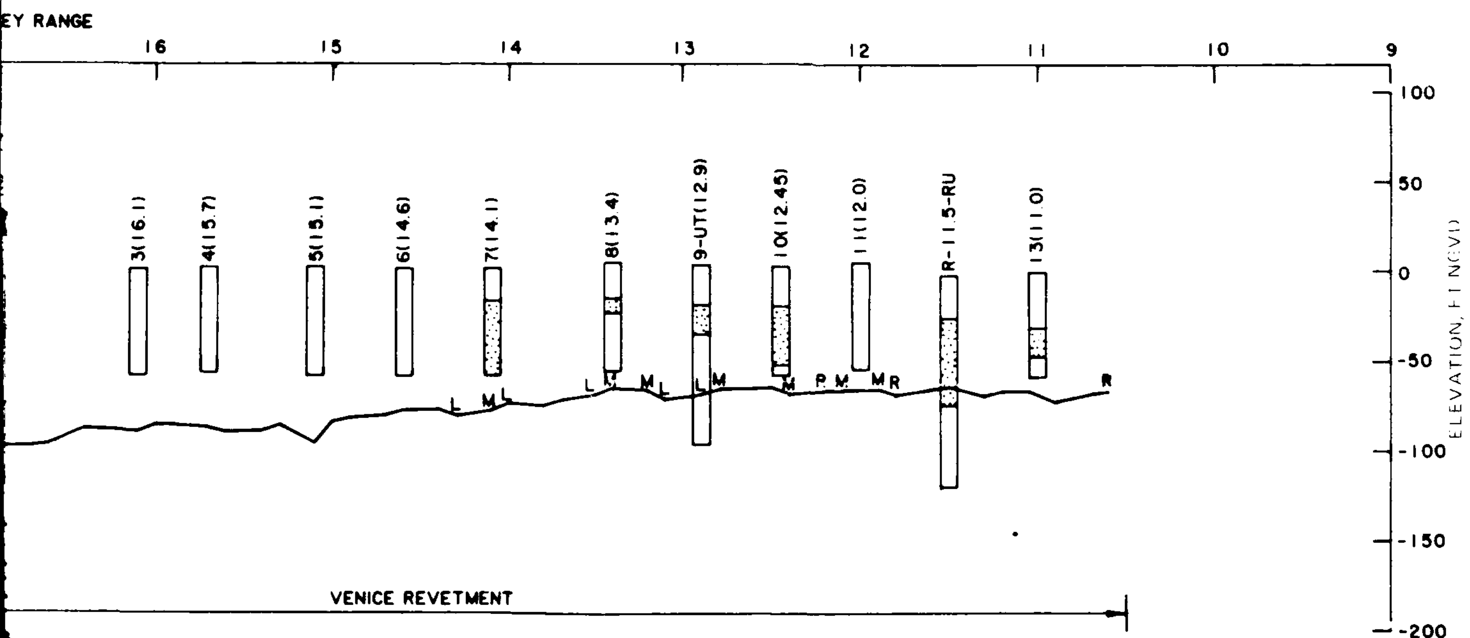

1973-1975 HYDROGRAPHIC SURVEY RANGE
37
36
35
34
33
32
31
30
29
R-37.2-R
R-37.0
R-36.6-UR
R-36.2-R
1-U(36.1)
R-35.6-R
R-35.4-R
1(35.0)
2(35.0)
R-34.9-R
3(34.7)
4(34.6)
5(34.3)
24-MH(34.2)
6(34.0)
7(33.8)
1-UT(33.5)
8(33.2)
9(33.0)
10(32.6)
R-32.4-UR
23-MH(32.3)
12(32.2)
R-32.0-R
2(31.8)
3(31.7)
1-UT(31.4)
4(31.35)
5(31.2)
22-MH(31.1)
6(31.0)
R-30.9-UR
R-30.8-R
21-MH(30.7)
R-30.3-R
20-MH(30.1)
19-MH(29.7)
18-MH(29.3)
17-MH(28.8)
R-28.55-R
16-MH(28.3)
R
L
L
R
THALWEG
NT
TROPICAL BEND REVETMENT


1973-1975 HYDROGRAPHIC SURVEY RANGE
20
19
18
17
16
15
14
13
12
R-20.2-R
R-19.6-R
8(18.9)
9-UHT(18.7)
1(17.9)
2(17.4)
R-16.9-RJ
3(16.1)
4(15.7)
5(15.1)
6(14.6)
7(14.1)
8(13.4)
9-UT(12.9)
10(12.45)
11(12.0)
R-11.5-RU
R
L
L M L
L M M L L M M R M M R
THALWEG
VENICE REVETMENT
RIGH
BA

1

2





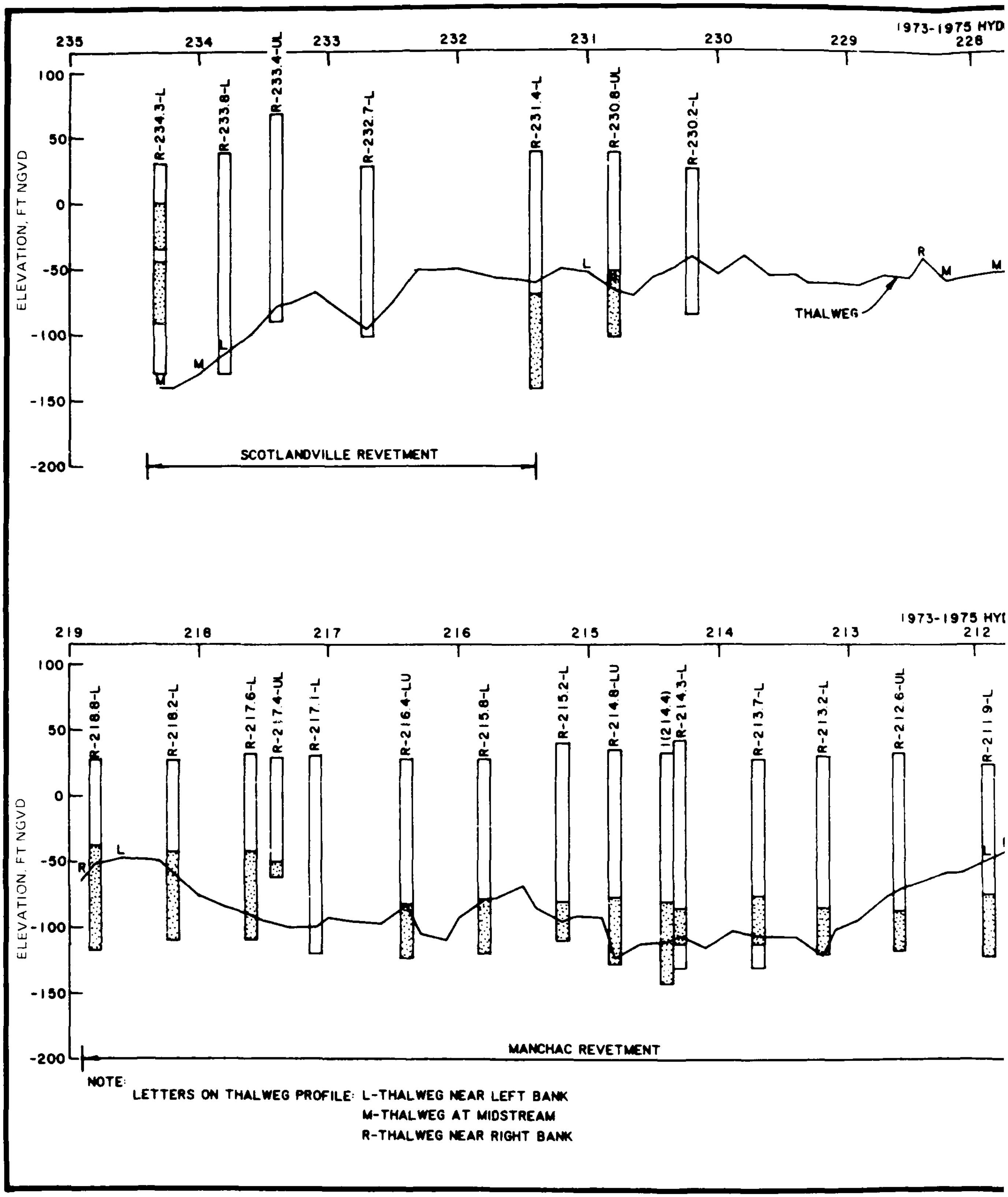
MISSISSIPPI RIVER

RIGHT DESCENDING BANK BORINGS

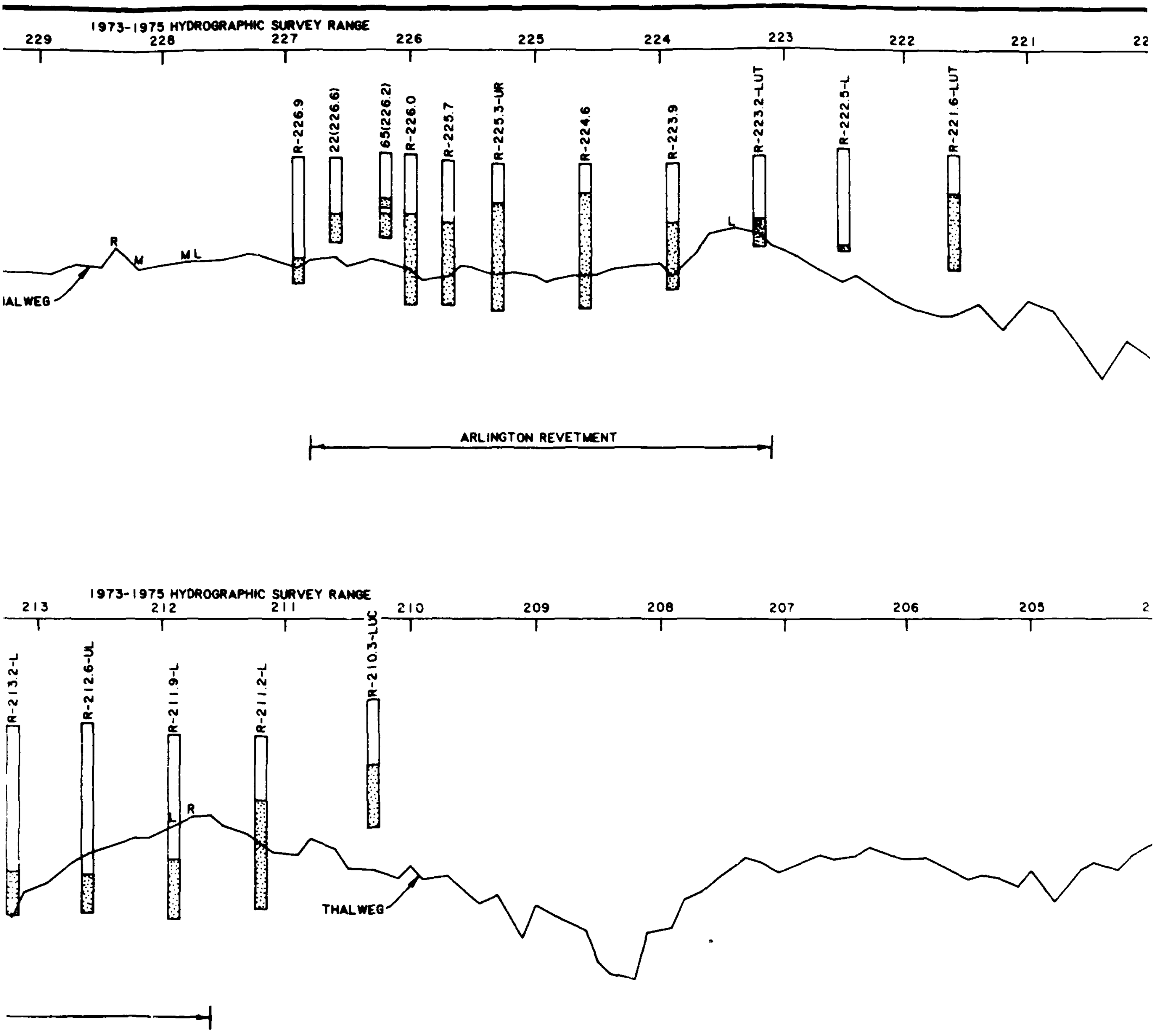
BATON ROUGE, LA., TO HEAD OF PASSES

2

3



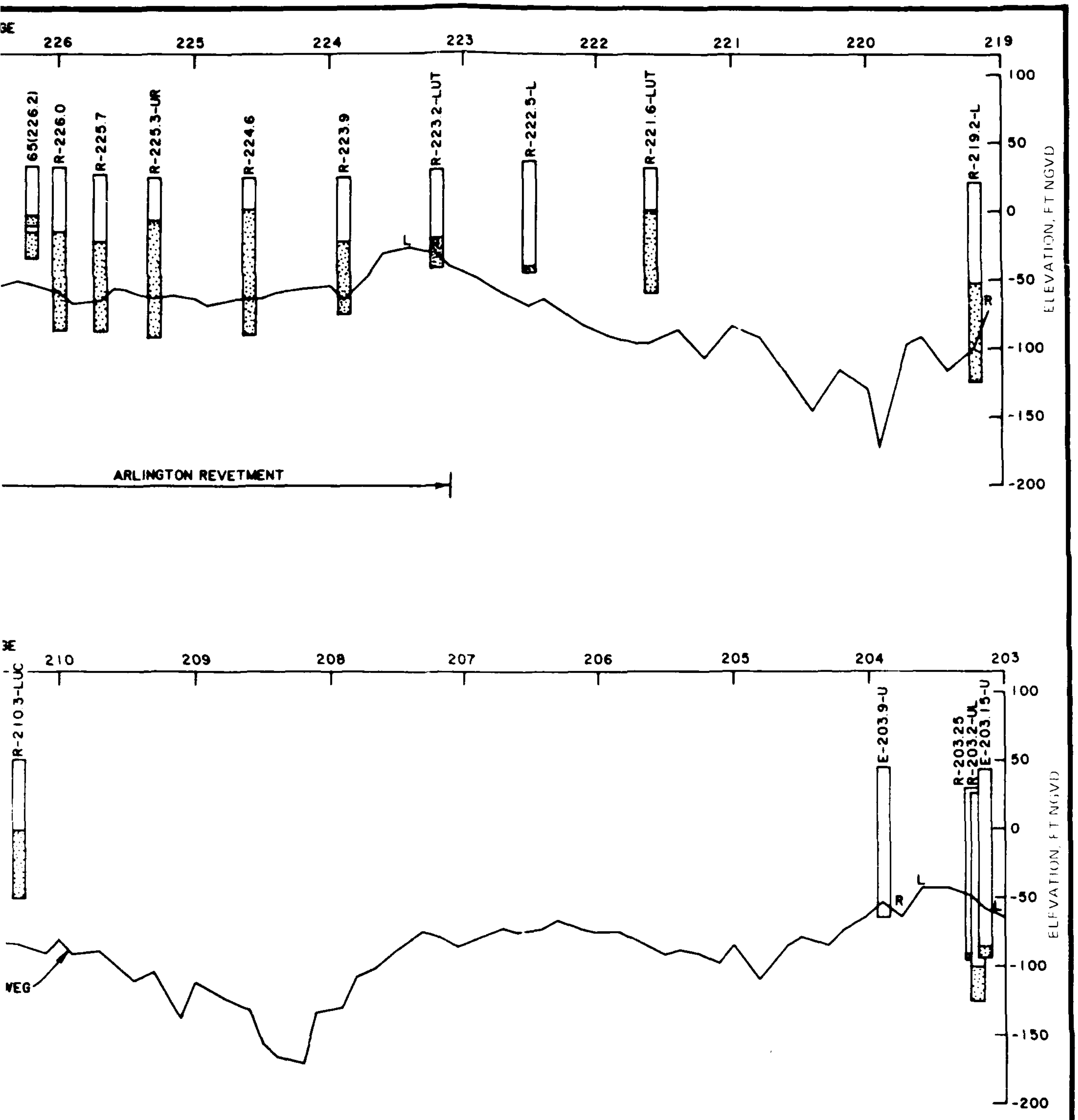
1973-1975 HYD
235
234
233
232
231
230
229
228
ELEVATION, FT NGVD
100
50
0
-50
-100
-150
-200
R-234.3-L
R-233.8-L
R-233.4-UL
R-232.7-L
R-231.4-L
R-230.8-UL
R-230.2-L
THALWEG
SCOTLANDVILLE REVETMENT
219
218
217
216
215
214
213
212
R-218.8-L
R-218.2-L
R-217.6-L
R-217.4-UL
R-217.1-L
R-216.4-LU
R-215.8-L
R-215.2-L
R-214.8-LU
I(214.4)
R-214.3-L
R-213.7-L
R-213.2-L
R-212.6-UL
R-211.9-L
MANCHAC REVETMENT
NOTE:
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK



MISSISSIPPI R

LEFT DESCENDING B

BATON ROUGE, LA., TO

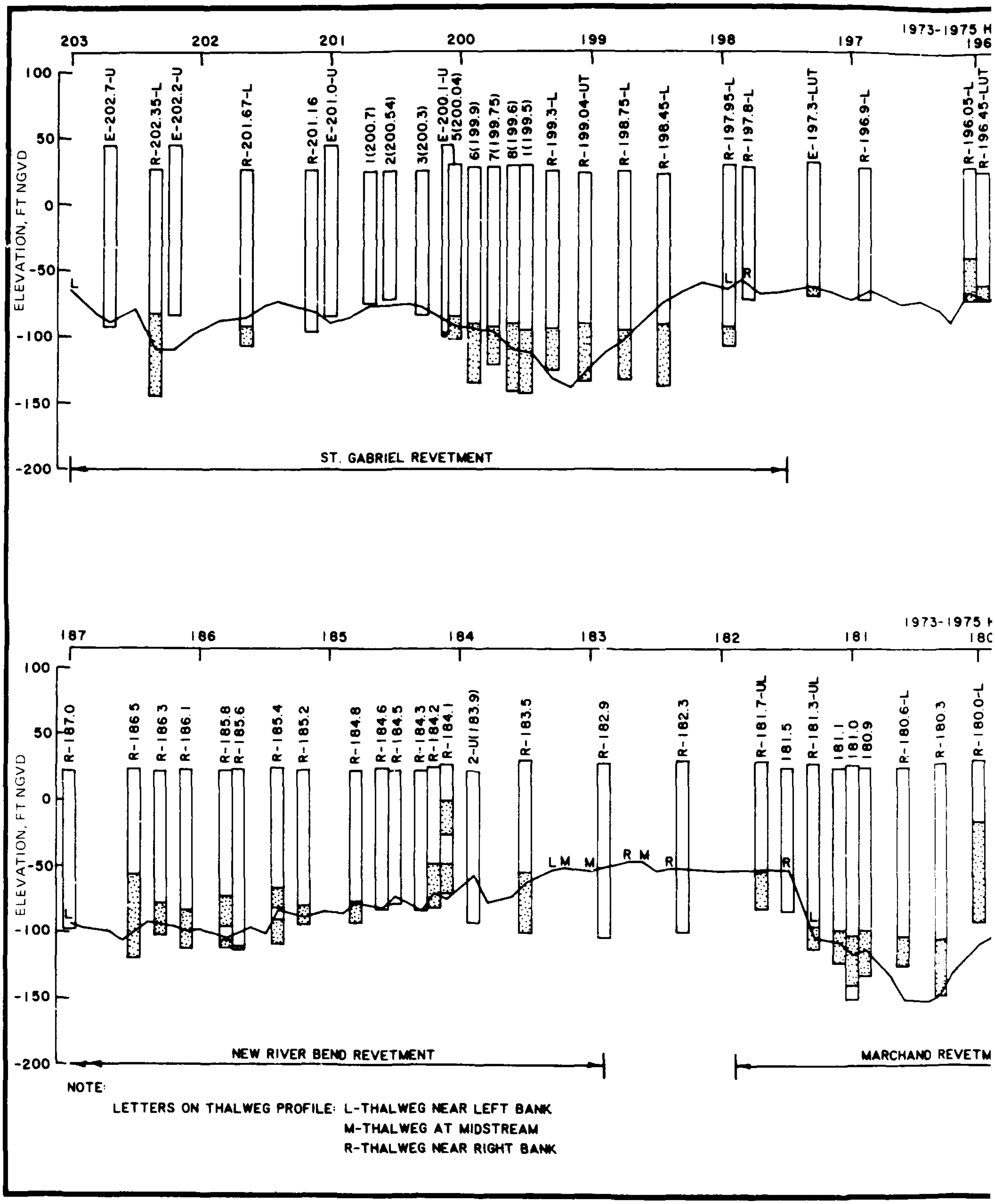


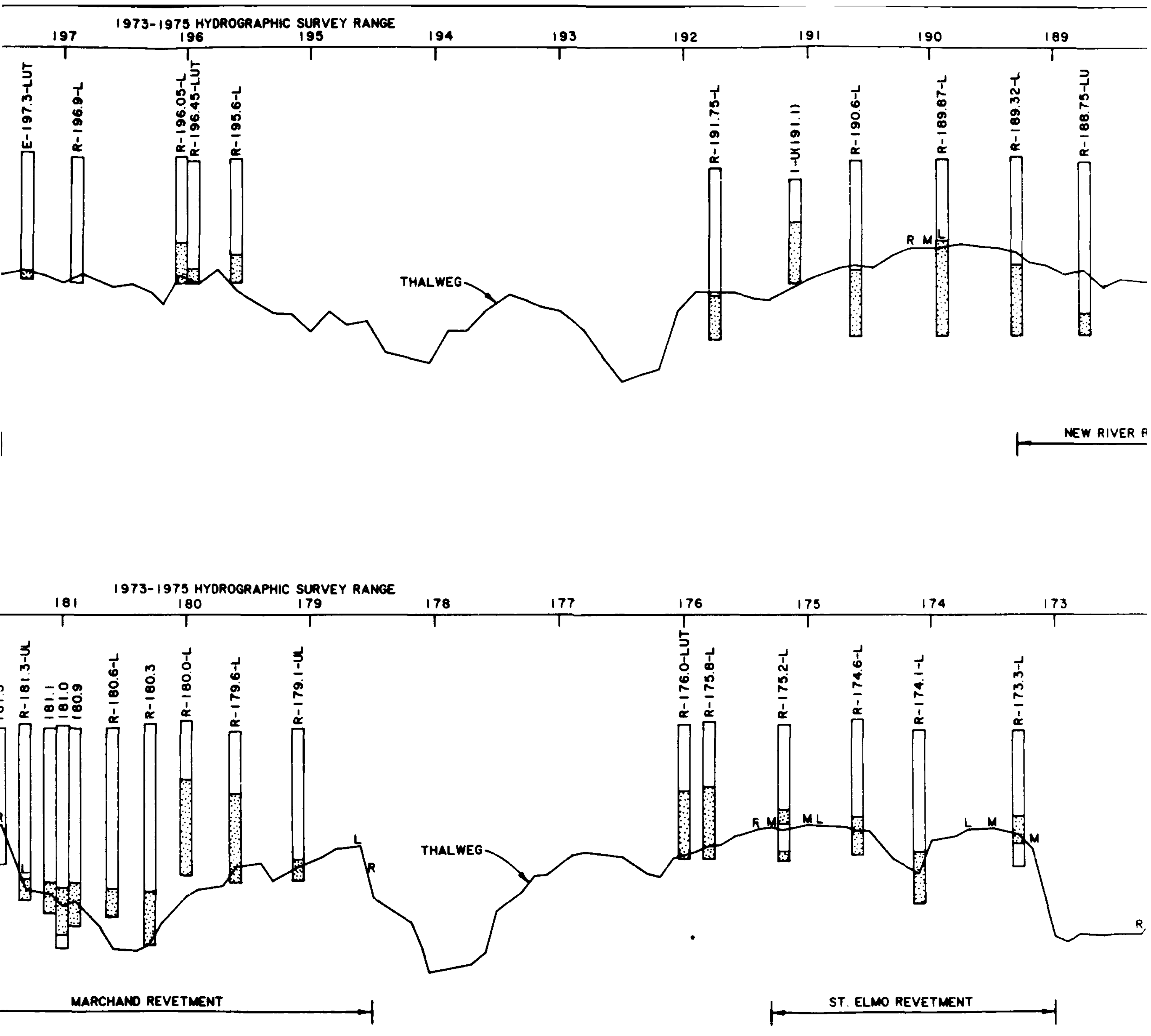
MISSISSIPPI RIVER

LEFT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES

2 3

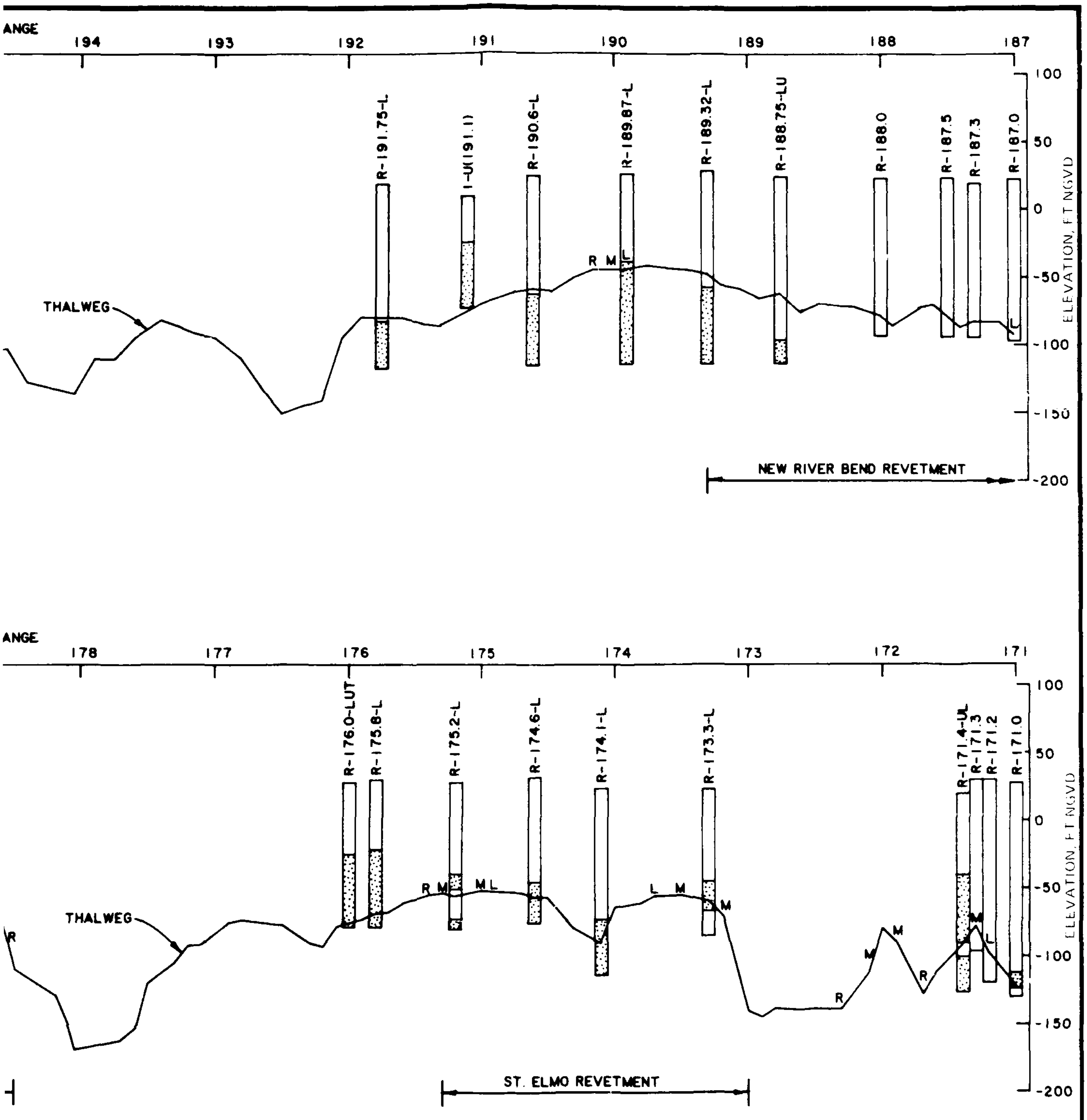

1973-1975 H
203
202
201
200
199
198
197
ELEVATION, FT NGVD
100
50
0
-50
-100
-150
-200
E-202.7-U
R-202.35-L
E-202.2-U
R-201.67-L
R-201.16
E-201.0-U
1(200.7)
2(200.54)
3(200.3)
E-200.1-U
5(200.04)
6(199.9)
7(199.75)
8(199.6)
1(199.5)
R-199.3-L
R-199.04-UT
R-198.75-L
R-198.45-L
R-197.95-L
R-197.8-L
E-197.3-LUT
R-196.9-L
R-196.05-L
R-196.45-LUT
ST. GABRIEL REVETMENT
1973-1975 H
187
186
185
184
183
182
181
180
R-187.0
R-186.5
R-186.3
R-186.1
R-185.8
R-185.6
R-185.4
R-185.2
R-184.8
R-184.6
R-184.5
R-184.3
R-184.2
R-184.1
2-U(183.9)
R-183.5
R-182.9
R-182.3
R-181.7-UL
181.5
R-181.3-UL
181.1
181.0
180.9
R-180.6-L
R-180.3
R-180.0-L
NEW RIVER BEND REVETMENT
MARCHAND REVETM
NOTE:
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK



MISSISSIP

LEFT DESCENDIN

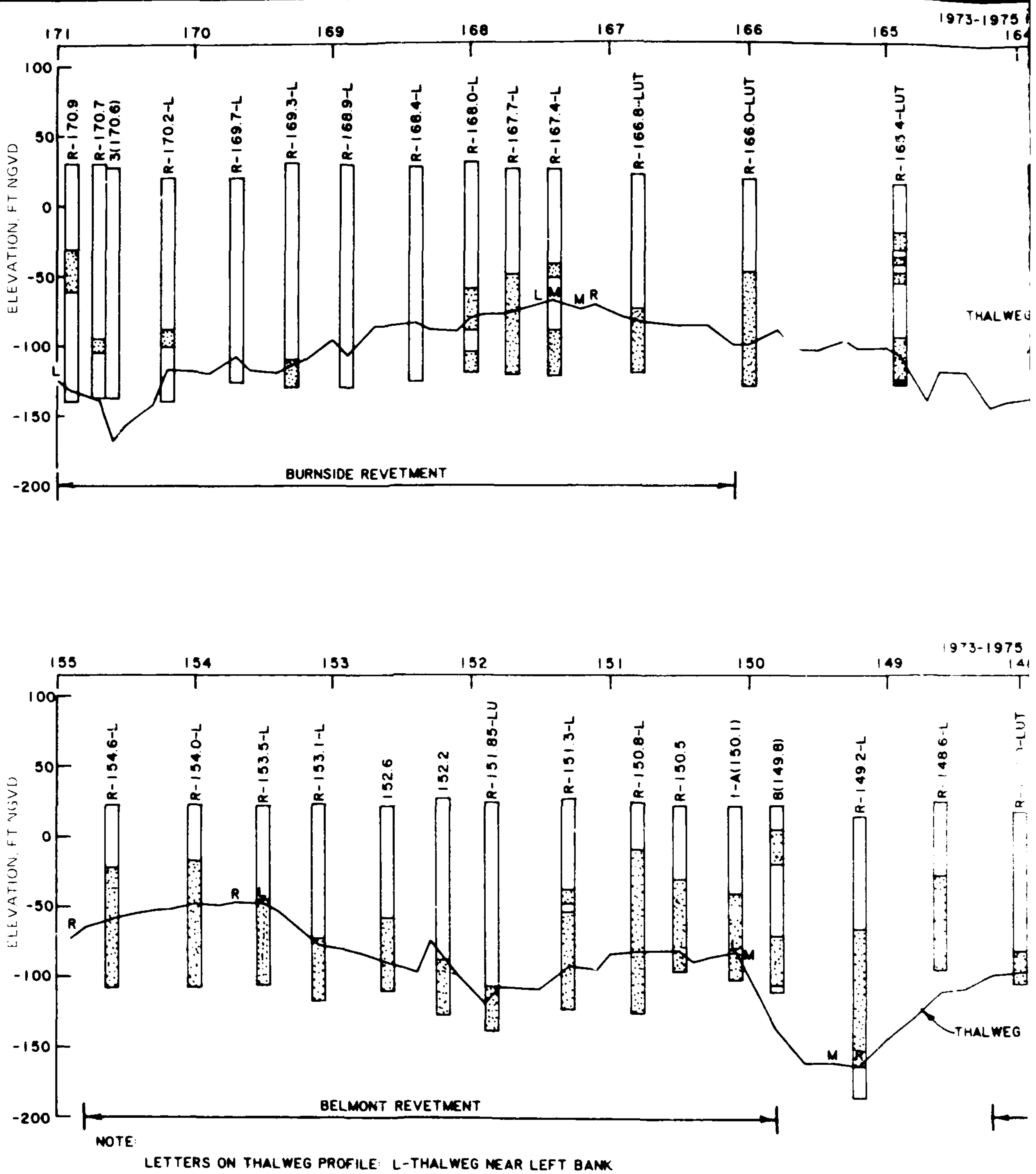
BATON ROUGE, LA



MISSISSIPPI RIVER

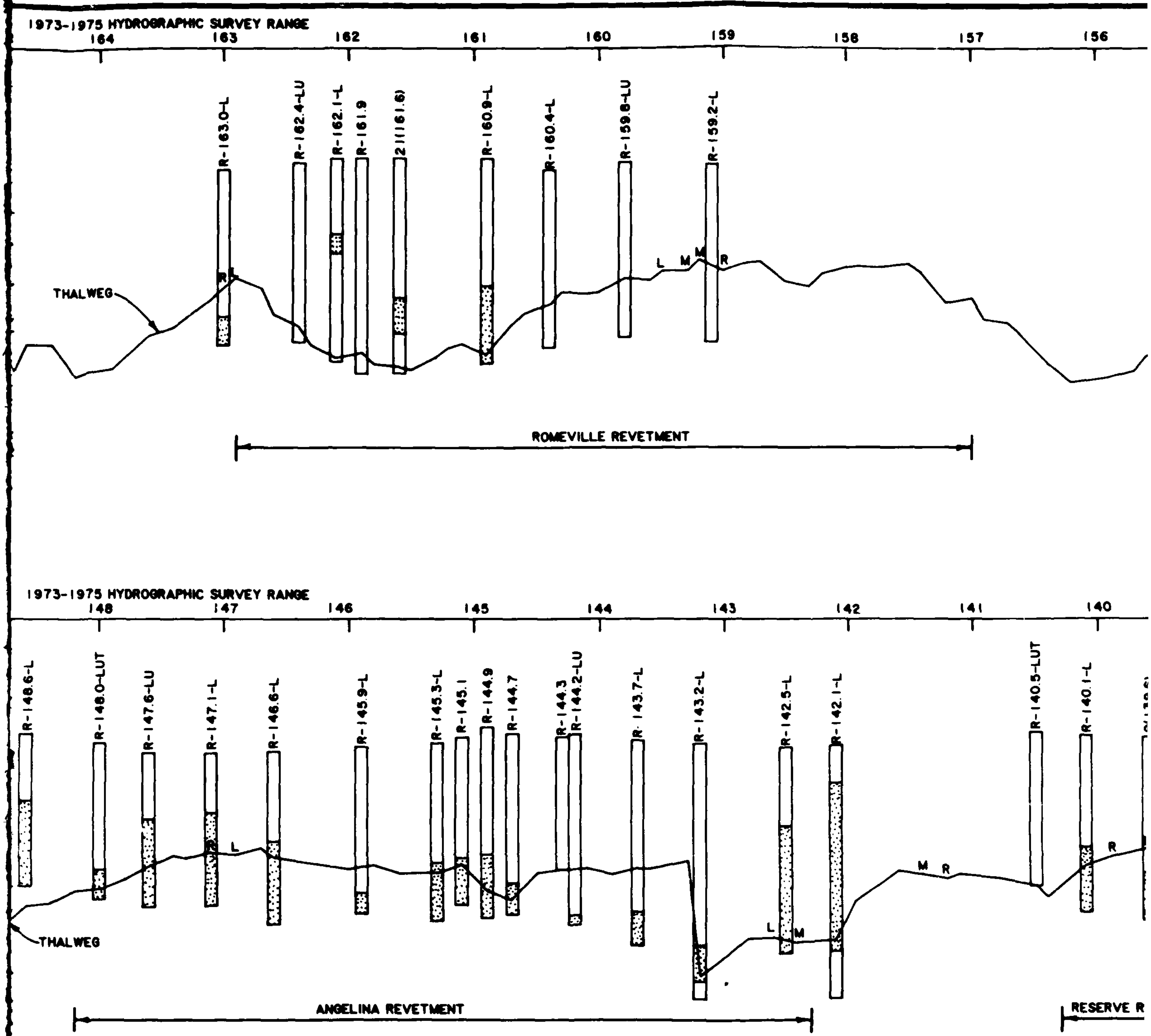
LEFT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES



NOTE:

LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK

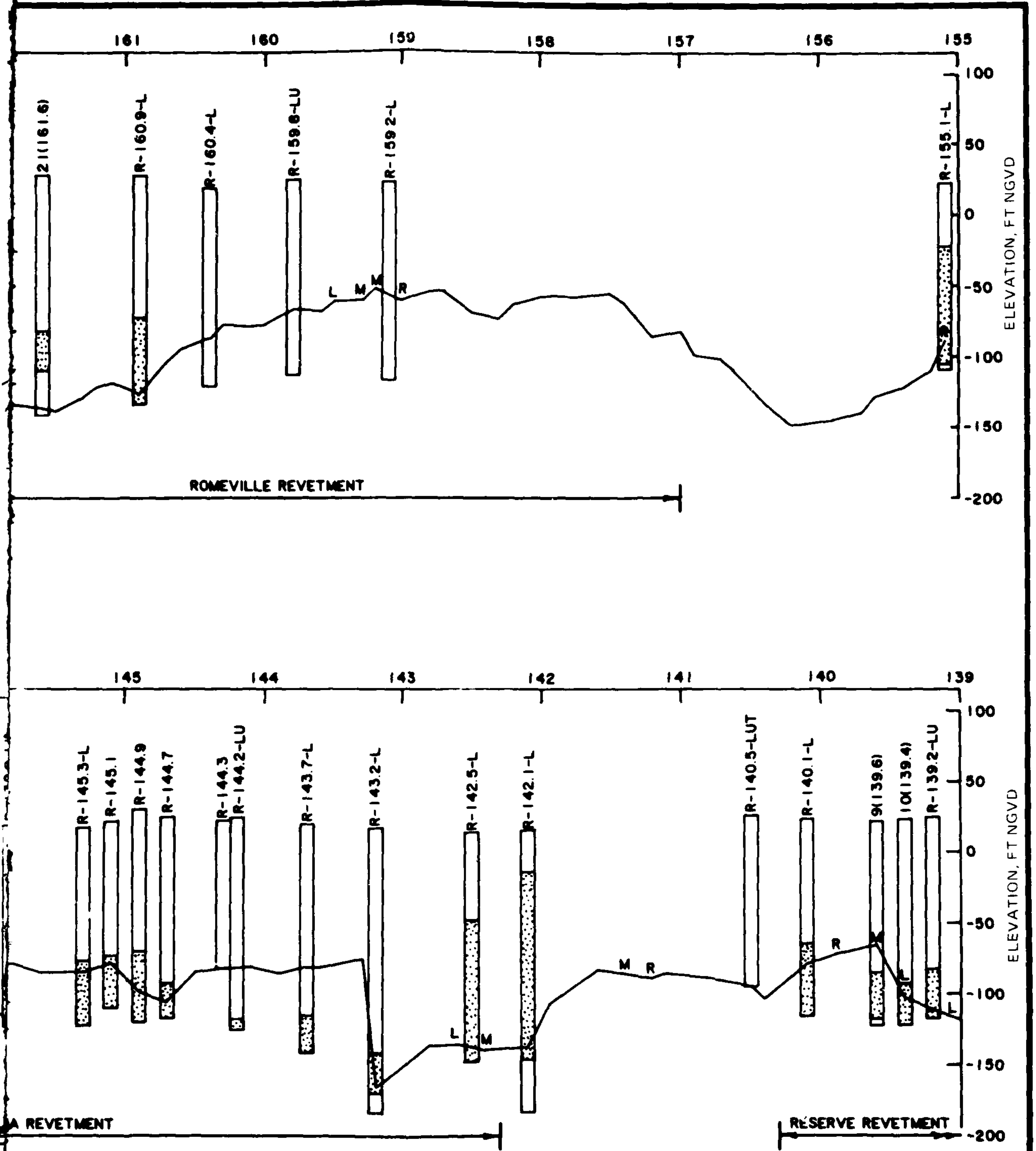


MISSISSIPPI RIVER

LEFT DESCENDING BANK

BATON ROUGE, LA., TO HEAD O

2 F



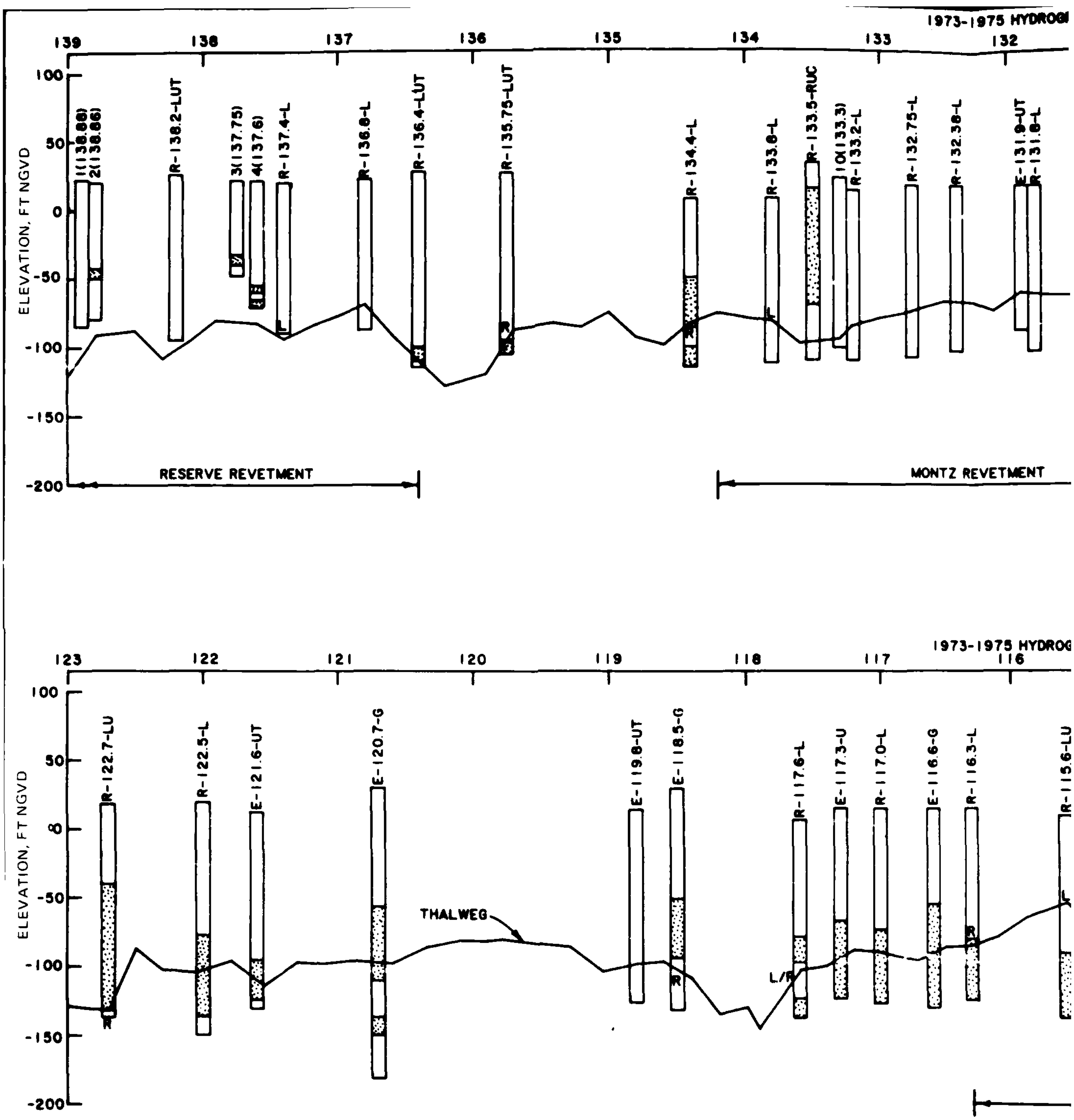
MISSISSIPPI RIVER

LEFT DESCENDING BANK BORINGS

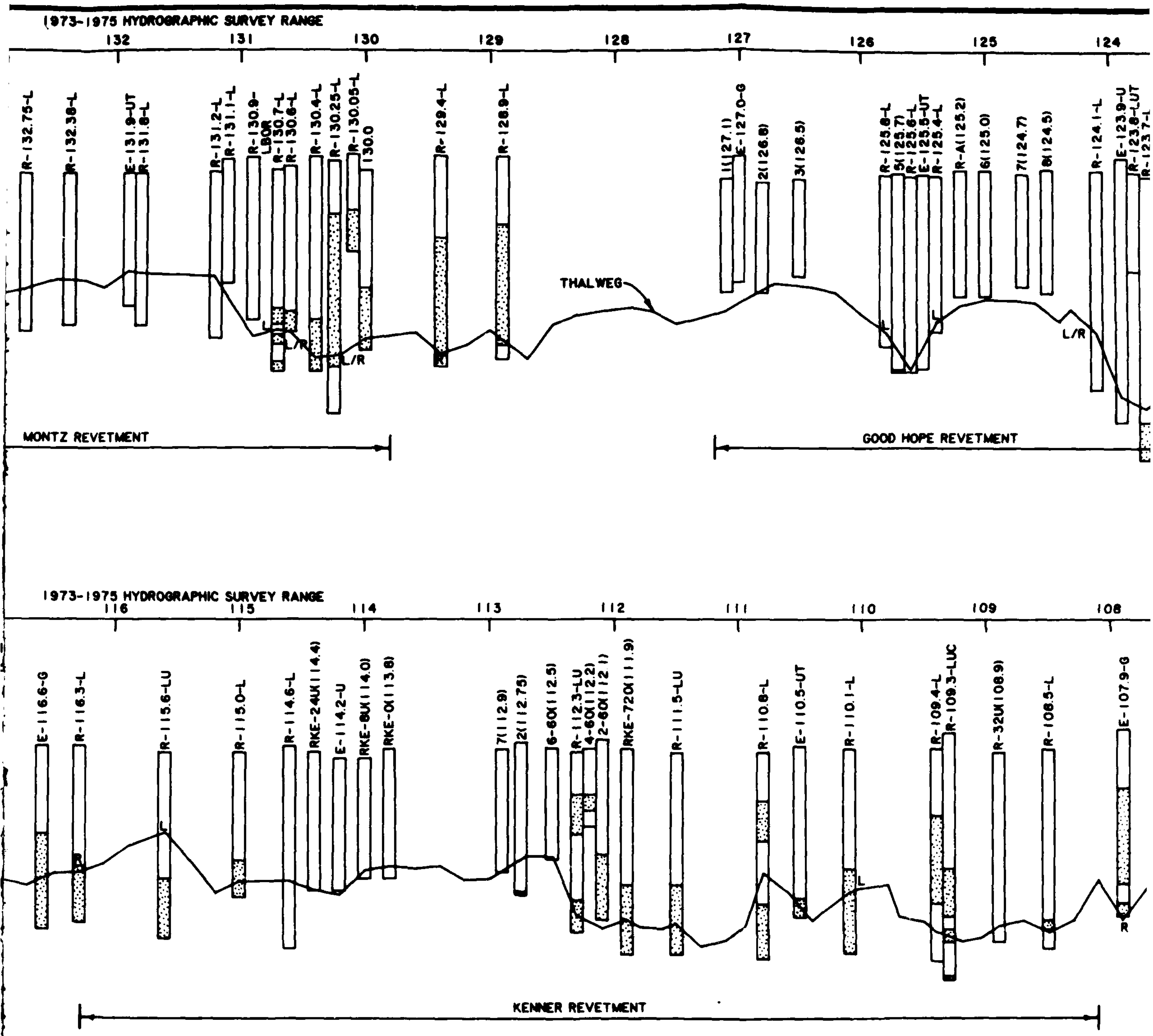
BATON ROUGE, LA., TO HEAD OF PASSES

PLATE B10

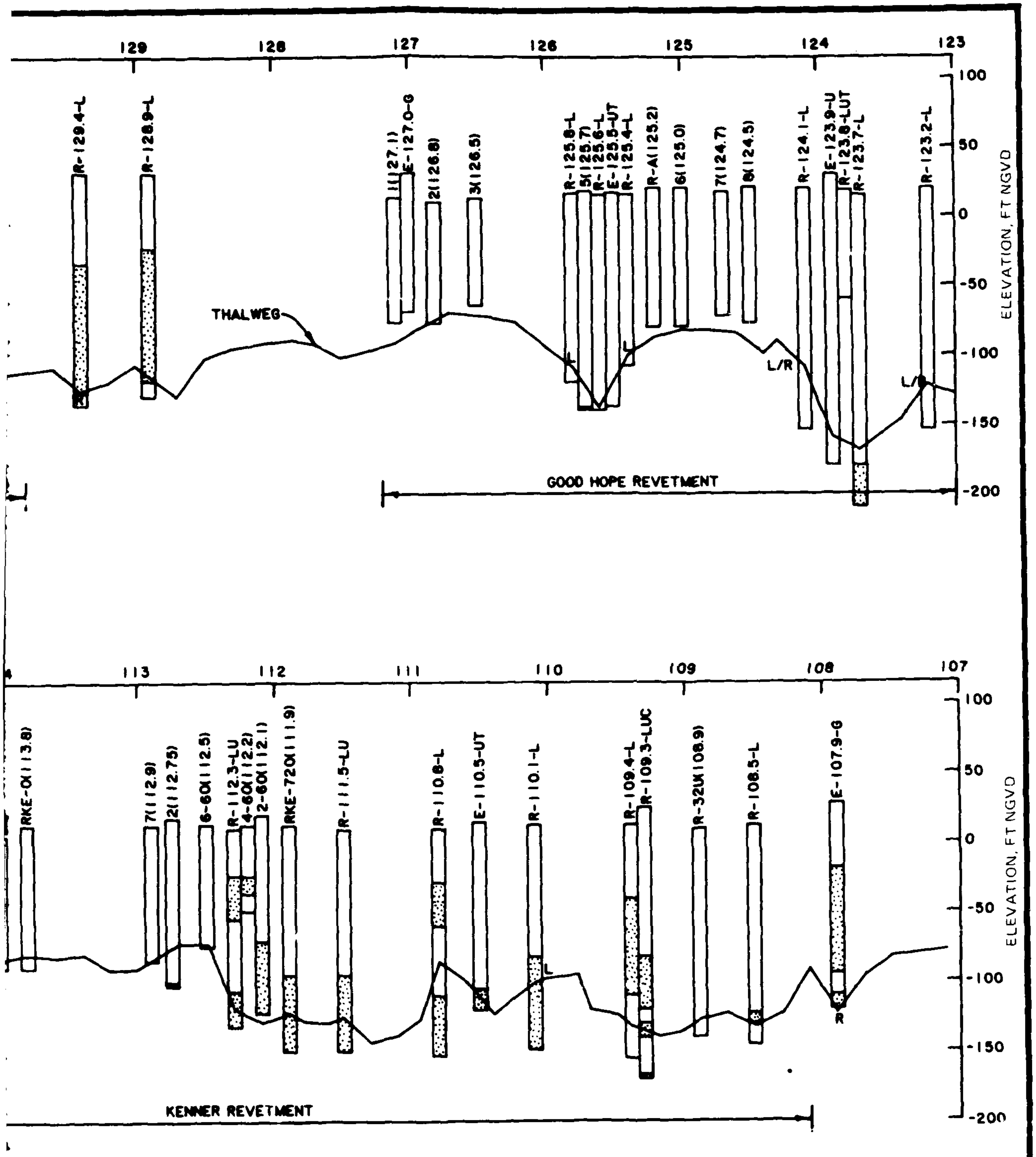
2 F , 3



NOTE:
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK



MISSISSIPPI RIVER
LEFT DESCENDING BANK
BATON ROUGE, LA., TO HEAD



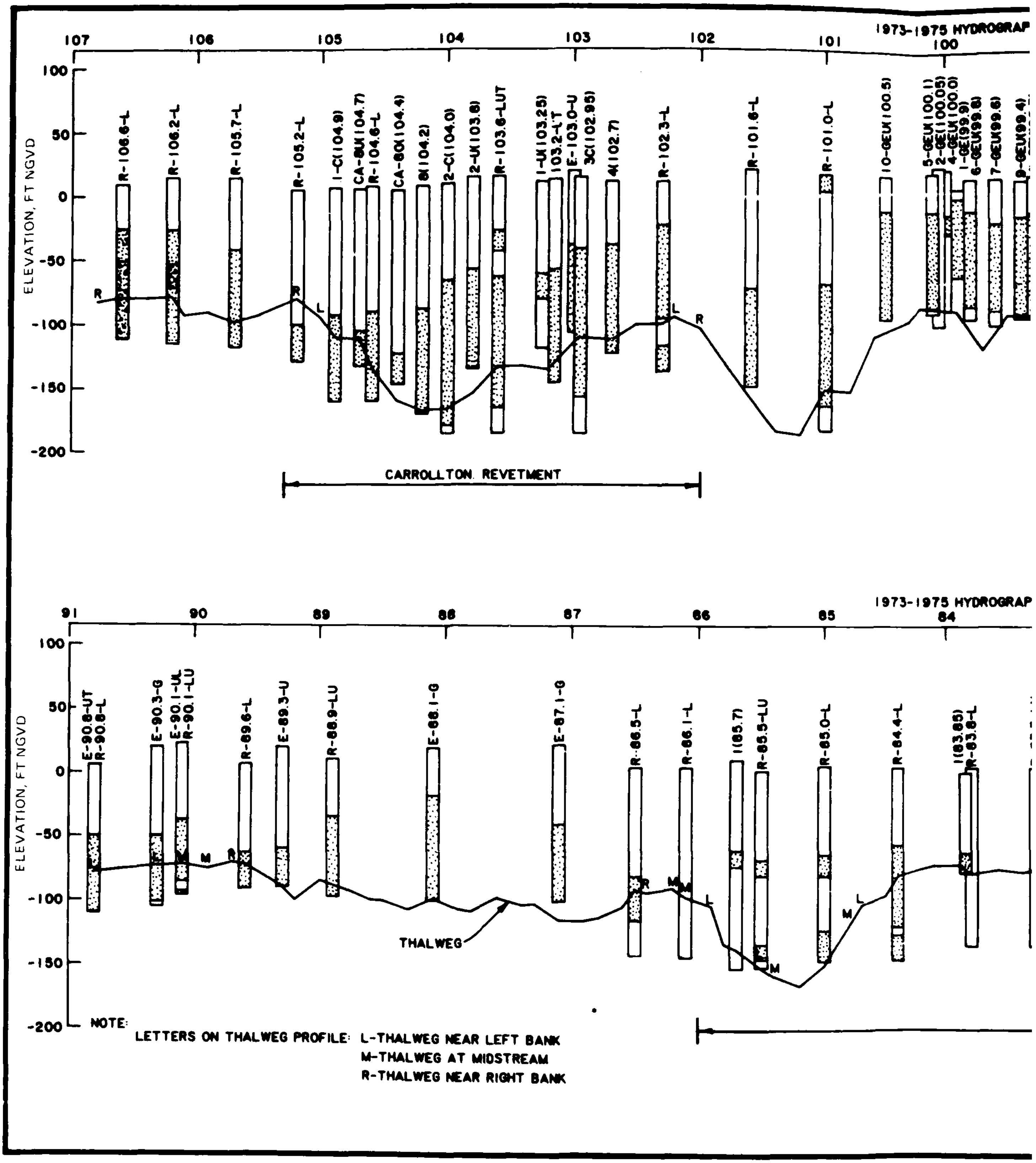
MISSISSIPPI RIVER

LEFT DESCENDING BANK BORINGS

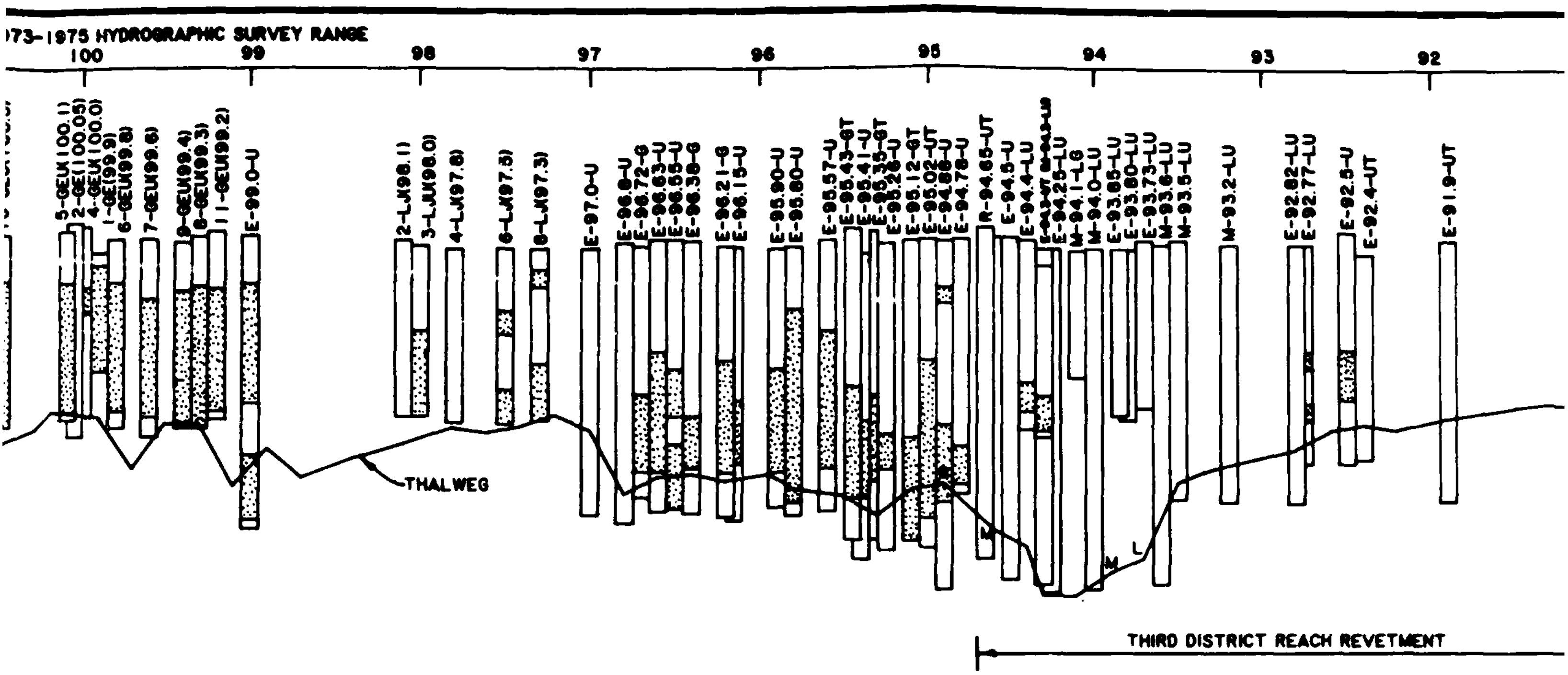
BATON ROUGE, LA., TO HEAD OF PASSES

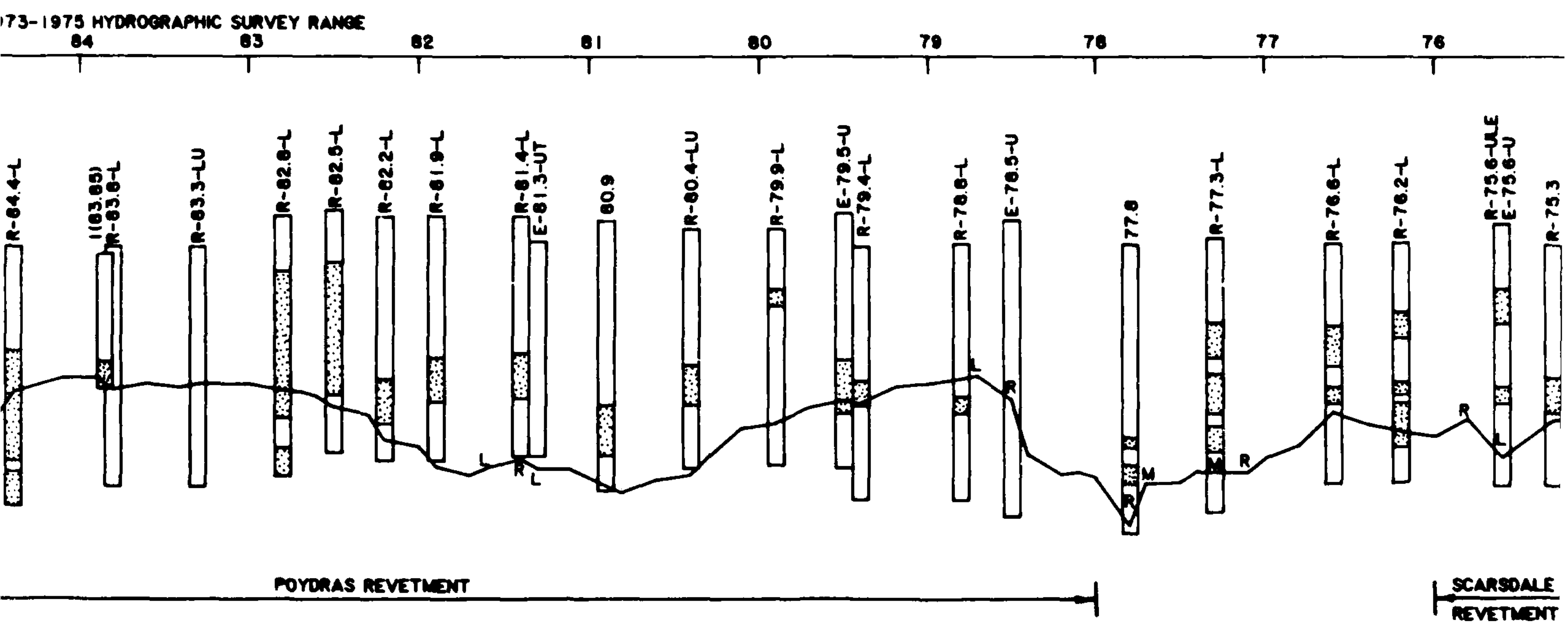
2

3



1973-1975 HYDROGRAP
ELEVATION, FT NGVD
CARROLLTON REVETMENT
THALWEG
NOTE:
LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK

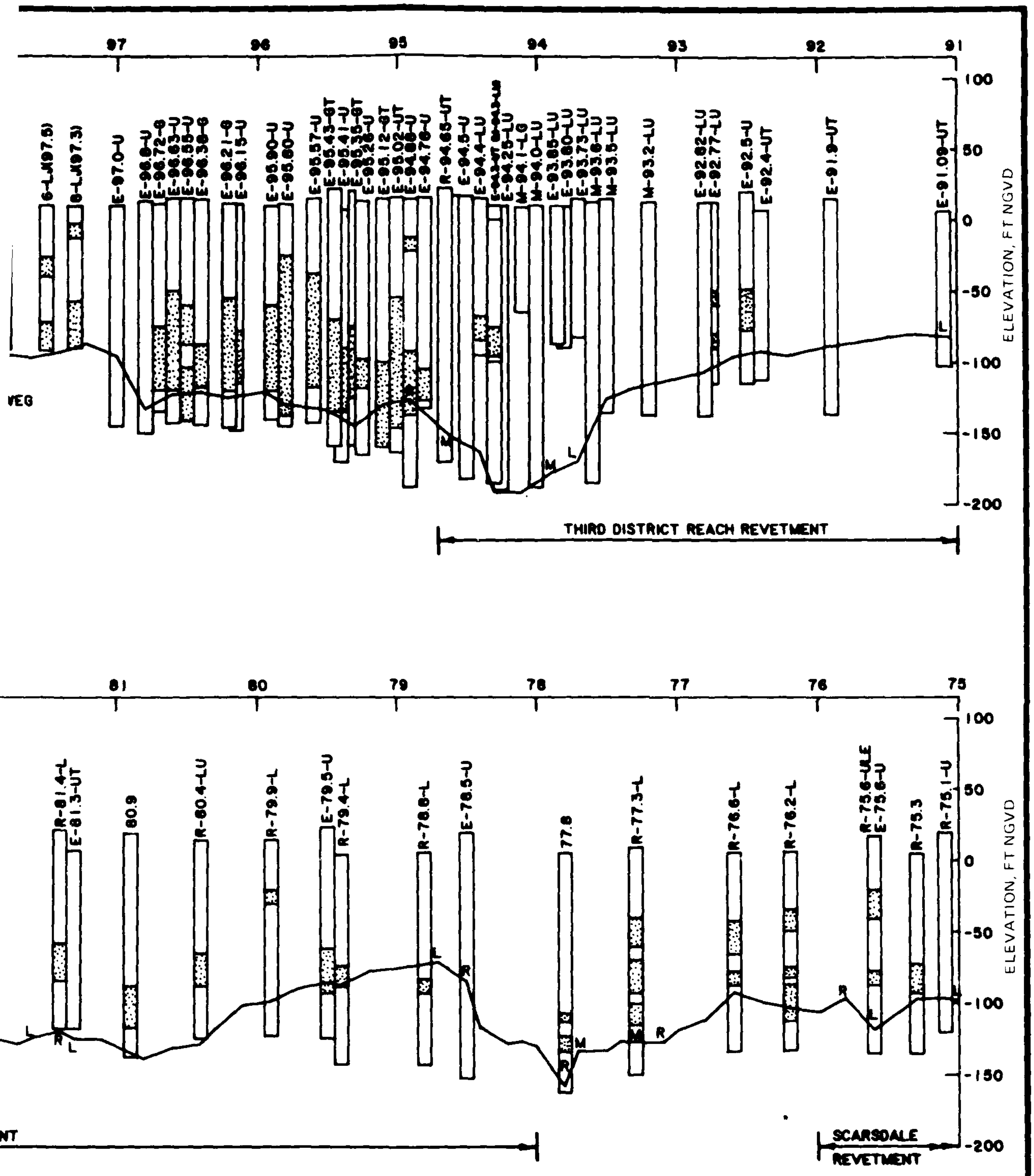




MISSISSIPPI RIVER

LEFT DESCENDING BANK BORIN

BATON ROUGE, LA., TO HEAD OF PAS



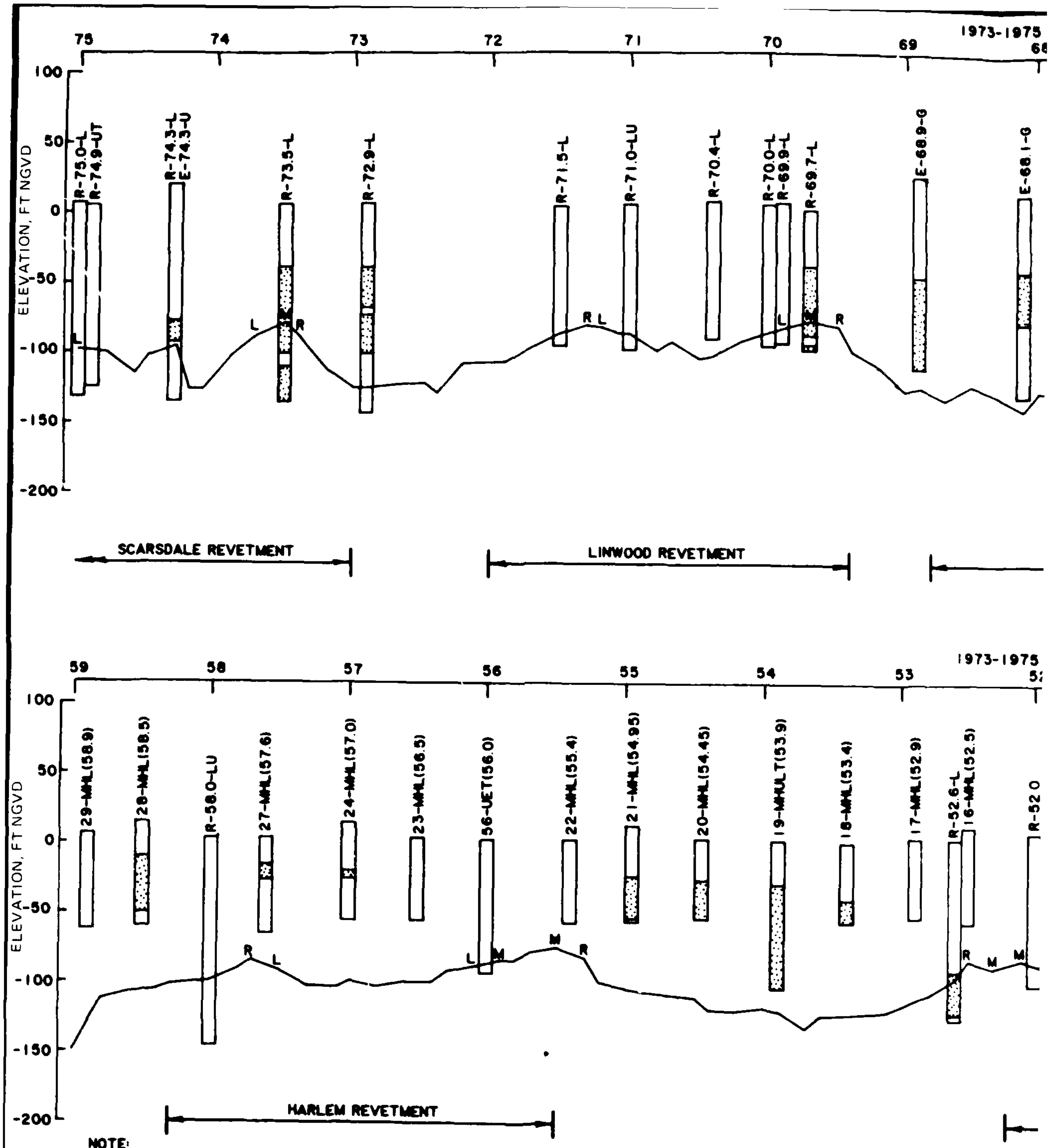
MISSISSIPPI RIVER

LEFT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES

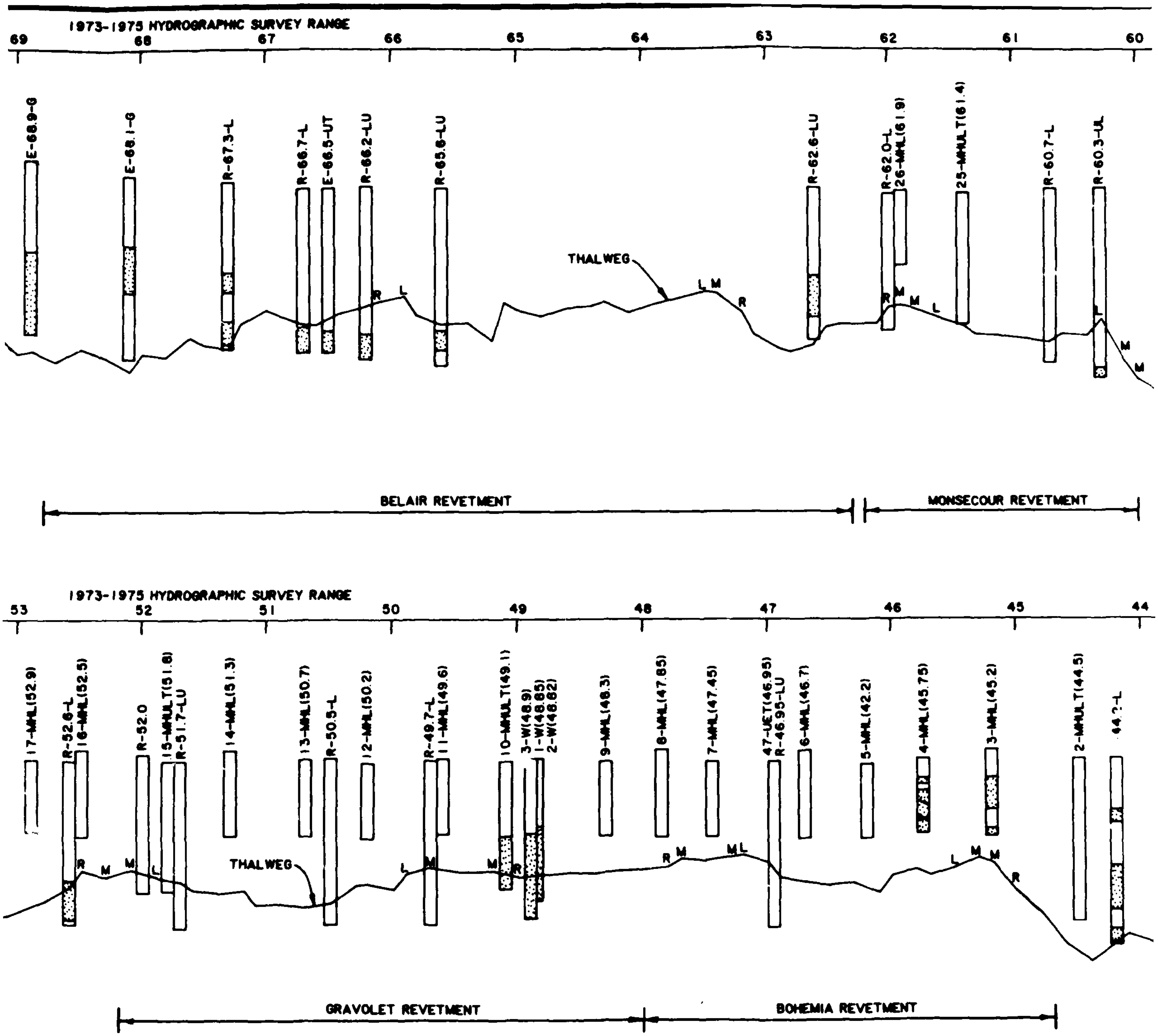
2

3



NOTE:

LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK

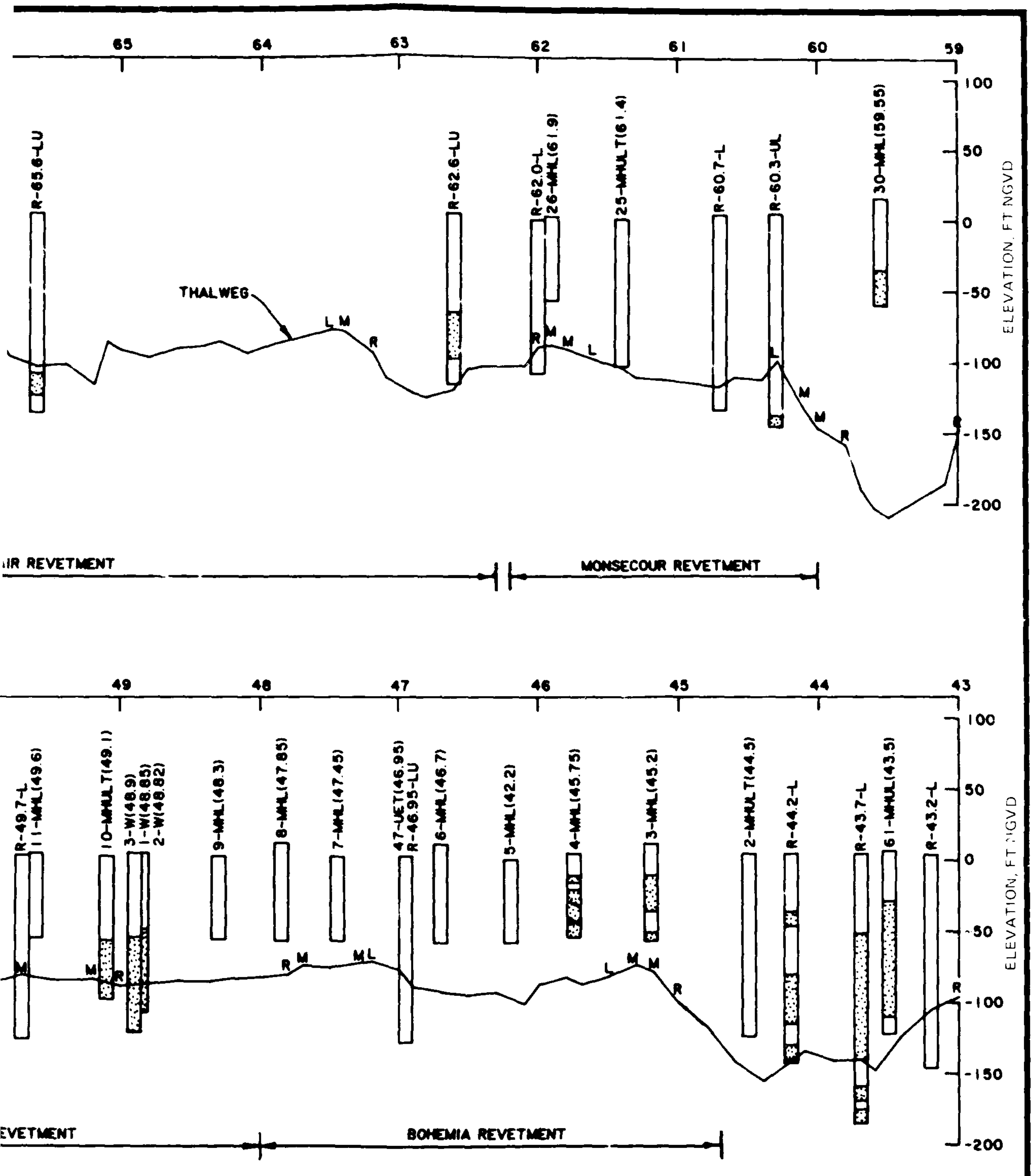


MISSISSIPPI RIVI

LEFT DESCENDING BA

BATON ROUGE, LA., TO HE

2



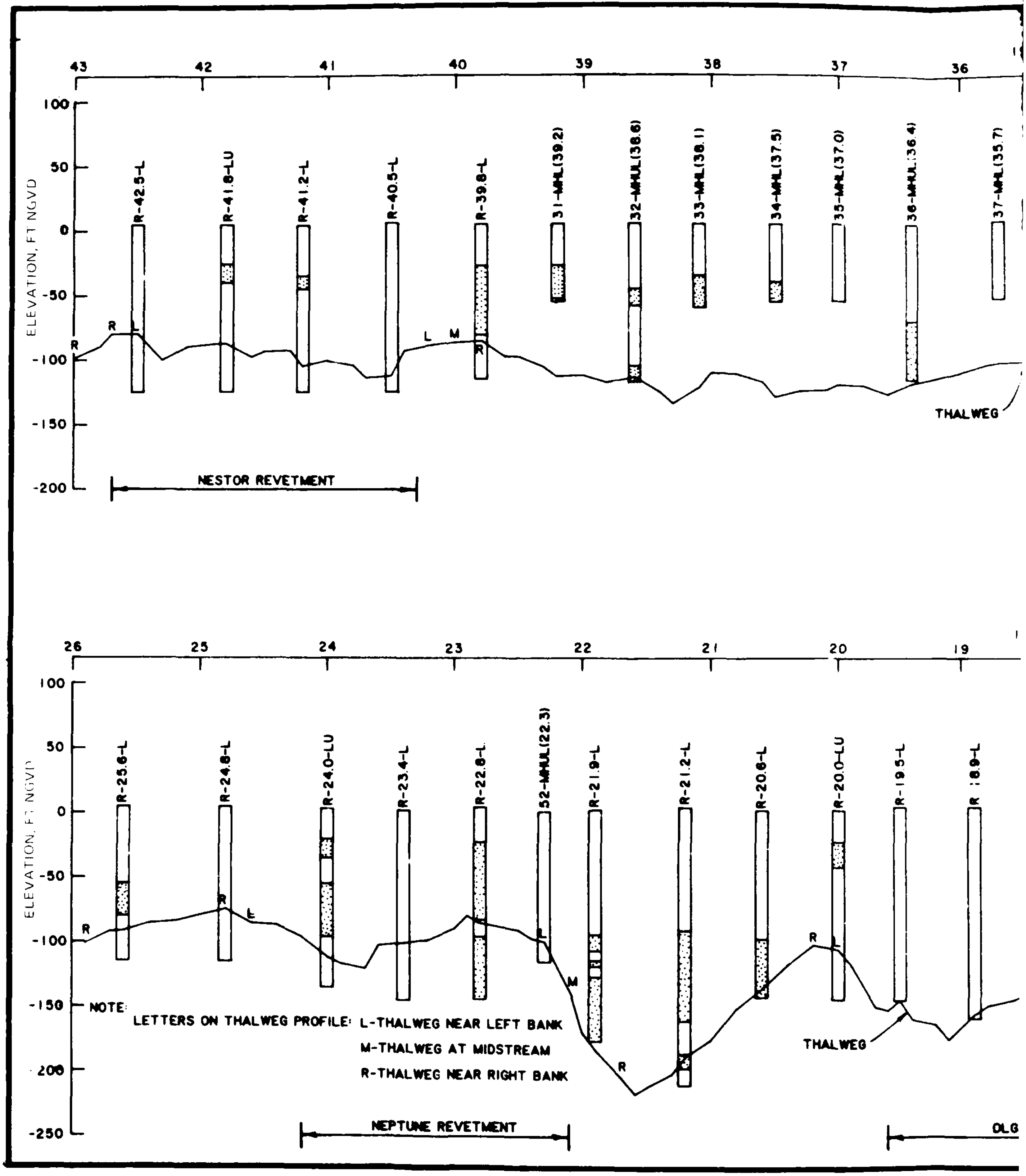
MISSISSIPPI RIVER

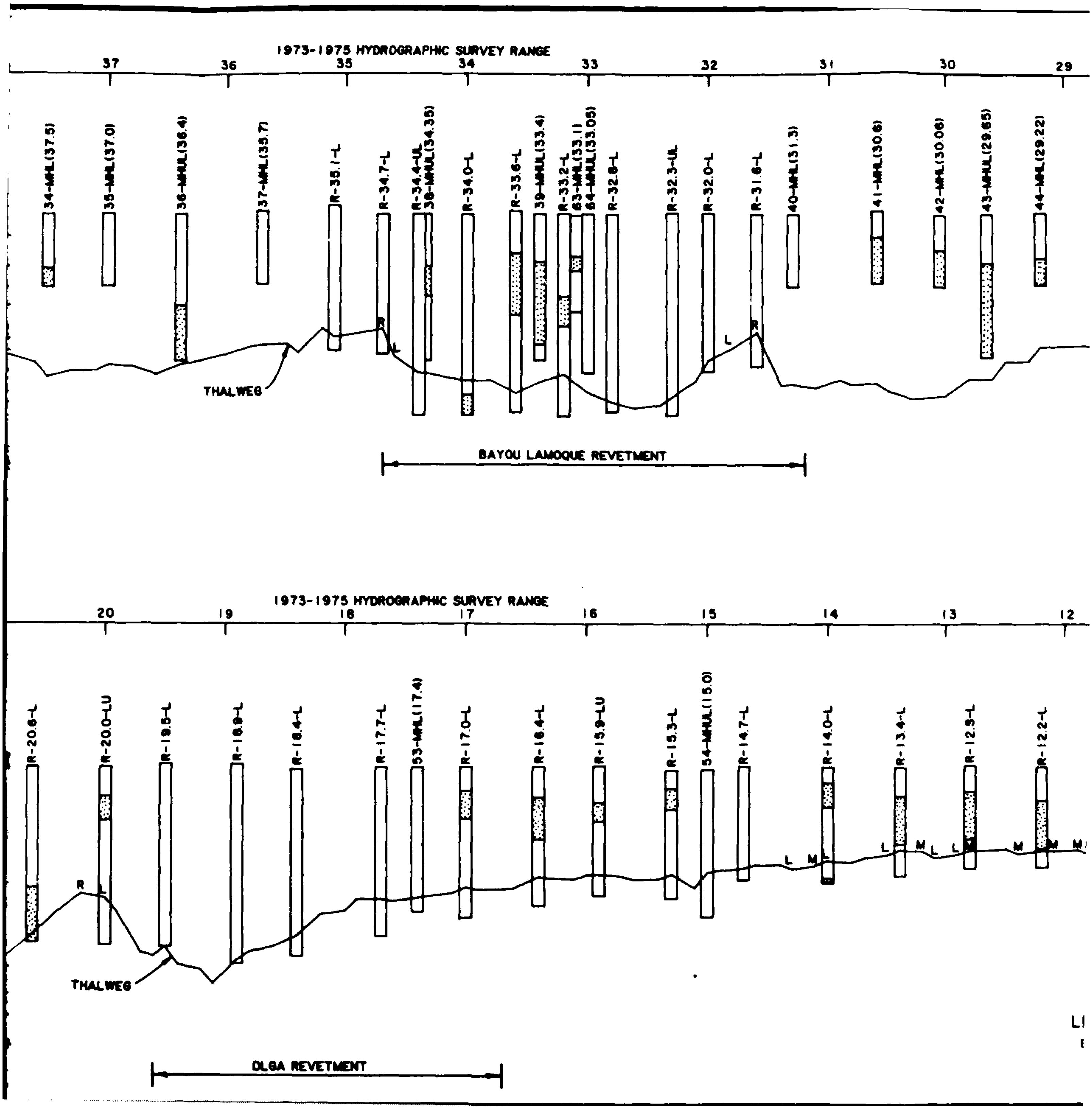
LEFT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES

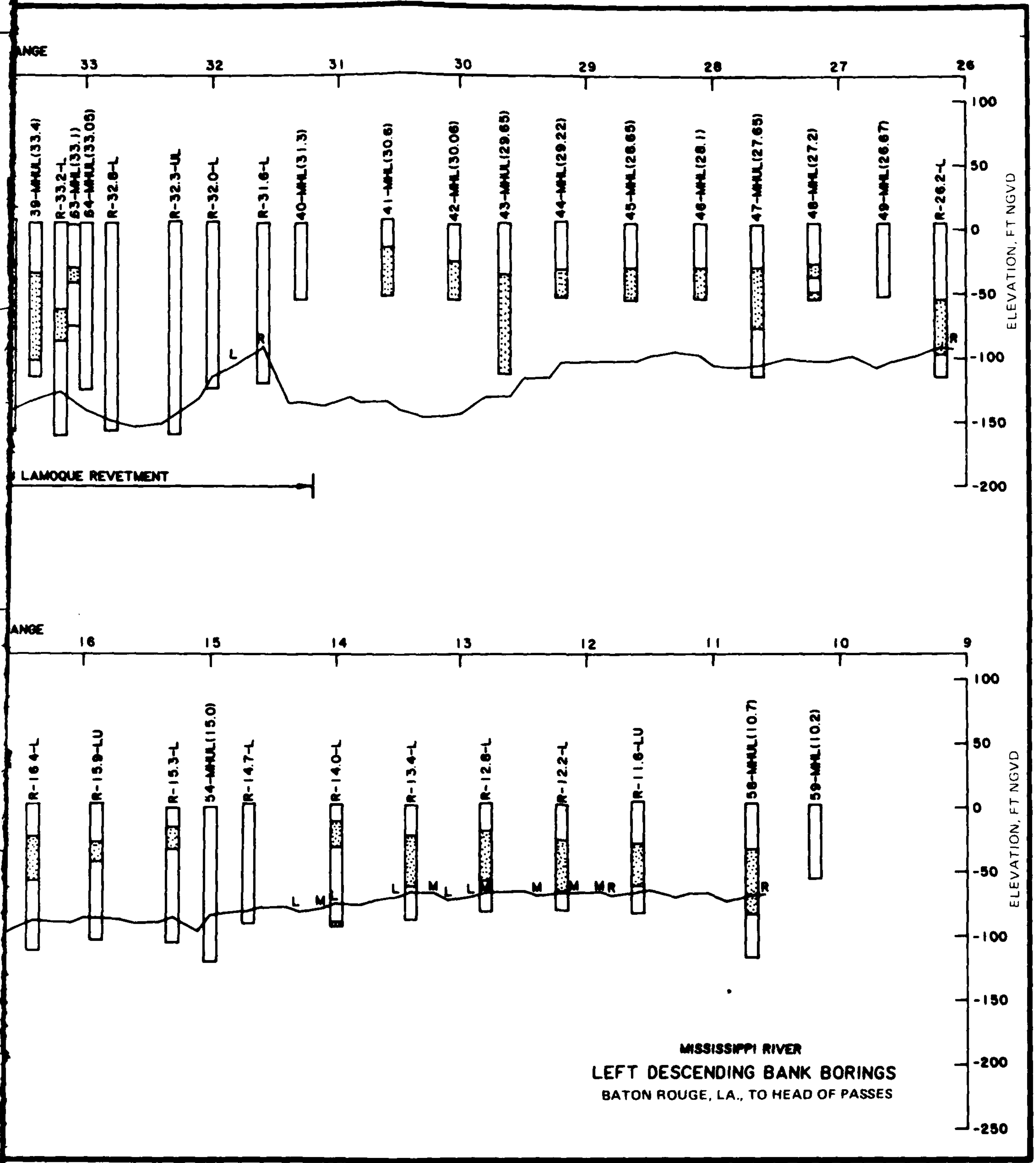
2

3


43
42
41
40
39
38
37
36
ELEVATION, FT NGVD
R-42.5-L
R-41.8-LU
R-41.2-L
R-40.5-L
R-39.8-L
31-MHL(39.2)
32-MHUL(38.6)
33-MHL(38.1)
34-MHL(37.5)
35-MHL(37.0)
36-MHUL(36.4)
37-MHL(35.7)
THALWEG
NESTOR REVETMENT
26
25
24
23
22
21
20
19
R-25.6-L
R-24.8-L
R-24.0-LU
R-23.4-L
R-22.8-L
52-MHUL(22.3)
R-21.9-L
R-21.2-L
R-20.6-L
R-20.0-LU
R-19.5-L
R-18.9-L
NOTE: LETTERS ON THALWEG PROFILE: L-THALWEG NEAR LEFT BANK
M-THALWEG AT MIDSTREAM
R-THALWEG NEAR RIGHT BANK
THALWEG
NEPTUNE REVETMENT
OLG



1973-1975 HYDROGRAPHIC SURVEY RANGE
37
36
35
34
33
32
31
30
29
34-MHL(37.5)
35-MHL(37.0)
36-MHL(36.4)
37-MHL(35.7)
R-35.1-L
R-34.7-L
R-34.4-UL
38-MHL(34.35)
R-34.0-L
R-33.6-L
39-MHL(33.4)
R-33.2-L
63-MHL(33.1)
64-MHL(33.05)
R-32.8-L
R-32.3-UL
R-32.0-L
R-31.6-L
40-MHL(31.3)
41-MHL(30.6)
42-MHL(30.06)
43-MHL(29.65)
44-MHL(29.22)
R
L
THALWEG
BAYOU LAMOQUE REVETMENT
1973-1975 HYDROGRAPHIC SURVEY RANGE
20
19
18
17
16
15
14
13
12
R-20.6-L
R-20.0-LU
R-19.5-L
R-18.9-L
R-18.4-L
R-17.7-L
53-MHL(17.4)
R-17.0-L
R-16.4-L
R-15.9-LU
R-15.3-L
54-MHL(15.0)
R-14.7-L
R-14.0-L
R-13.4-L
R-12.9-L
R-12.2-L
THALWEG
OLGA REVETMENT



MISSISSIPPI RIVER

LEFT DESCENDING BANK BORINGS

BATON ROUGE, LA., TO HEAD OF PASSES

2

3

APPENDIX C

DISCRETE HISTORICAL EROSION/DEPOSITION DATA
MISSISSIPPI RIVER BELOW BATON ROUGE, LA

Table C1

Riverbank Erosion (minus) and Accretion (plus) in Feet Based on Approximate Low Water Reference Plane and Bank Lines of the 1883-1894 Versus the 1973-1975 Hydrographic Surveys

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
234.8	400	-230
234.4	800	-170
234.2	330	-470
233.8	100	-70
233.4	0	130
233.1	0	270
232.7	200	100
232.5	0	0
232.2	170	-100
231.9	0	0
231.5	0	0
231.2	0	-70
231.0	100	0
230.65	330	0
230.3	300	-70
230.0	400	-230
229.6	350	-200
229.3	100	-225
228.9	200	-450
228.5	200	-275
228.2	400	-400
227.8	450	-450
227.2	-50	125
226.8	-150	600
226.5	-400	1,000
226.2	-700	1,450
225.9	-900	1,725
225.6	-1,425	1,750
225.3	-1,700	1,700
225.0	-1,650	1,600
224.7	-950	1,500
224.4	-350	1,300
224.0	100	1,000
223.7	175	725
223.4	25	550
223.1	100	200
222.7	-50	0
222.4	0	125
221.9	1,425	-450
221.6	1,850	-500
221.2	2,450	-900
220.8	2,400	-1,450
220.4	3,000	-2,150
220.0	3,350	-2,550
219.7	3,000	-2,300
219.4	2,200	-1,400
219.1	1,400	-750
218.8	600	-300
218.5	-325	300
218.2	-725	775
217.8	-1,200	1,000
217.5	-1,125	1,525
217.1	-850	1,400
216.8	-300	700
216.4	0	800
216.1	200	600
215.8	250	800
215.5	200	900
215.2	0	1,550
214.9	-400	1,600
214.6	-1,000	1,000
214.3	-1,150	1,450

(Continued)

(Sheet 1 of 10)

Table Cl (Continued)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
213.9	-1,000	1,650
213.6	-900	1,450
213.2	-550	1,100
212.9	-550	550
212.6	-500	400
212.2	-100	400
211.9	0	200
211.6	350	0
211.3	625	-250
211.0	700	-590
210.8	550	-825
210.5	0	-1,000
210.1	-150	-1,050
209.9	-100	-800
209.6	-150	-400
209.3	150	-400
209.0	200	-350
208.6	750	-100
208.4	1,100	-400
208.1	1,300	-300
207.8	1,050	-150
207.5	600	-200
206.7	-150	-200
206.4	0	-100
206.15	100	-400
205.85	900	-700
205.5	1,350	-1,175
205.24	1,700	-1,550
205.0	2,150	-1,550
204.6	2,700	-1,850
204.3	2,800	-1,200
204.0	2,600	-350
203.75	2,000	200
203.4	1,125	400
203.13	250	300
202.8	-100	0
202.5	-400	250
202.2	-325	175
201.84	-200	100
201.5	-250	0
201.16	-100	-100
200.85	50	-100
200.54	200	-100
200.33	-150	-200
199.9	-700	600
199.6	-1,200	1,300
199.3	-1,300	1,850
199.04	-1,000	1,825
198.75	-300	1,100
198.45	-200	400
198.15	-50	0
197.85	75	-300
197.56	150	-300
197.3	0	-250
197.0	-200	-150
196.85	-200	-175
196.45	-50	-125
196.18	100	-150
195.9	200	-350
195.6	0	-400
195.32	200	-500
194.98	350	-1,000
194.7	300	-1,300
194.4	400	-1,075
194.05	750	-600
193.75	1,000	-225
193.44	500	-200

(Continued)

(Sheet 2 of 10)

Table C1 (Continued)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
193.13	600	-400
192.82	900	-850
192.48	1,400	-1,000
192.2	1,500	-750
191.9	1,000	-600
191.6	300	-125
191.3	-50	50
191.02	-150	0
190.75	-125	100
190.45	0	0
190.15	0	0
189.87	100	-100
189.59	50	0
189.32	0	150
189.04	0	300
188.75	-100	325
188.46	-250	450
188.2	-600	700
187.9	-900	1,000
187.6	-1,025	2,000
187.3	-1,200	1,000
187.0	-1,500	1,150
186.7	-1,400	1,400
186.4	-1,500	2,225
186.1	-1,400	2,400
185.8	-1,400	2,350
185.5	-1,400	2,350
185.2	-1,400	2,000
184.9	-1,000	1,900
184.6	-900	1,900
184.3	-700	1,550
184.1	-400	1,250
183.8	-250	950
183.5	-300	700
183.2	-100	200
182.9	0	0
182.6	100	-200
182.0	50	-300
181.7	200	-150
181.5	0	375
181.1	-400	950
181.0	-950	1,500
180.7	-1,700	2,000
180.4	-1,650	2,250
180.2	-1,650	2,900
179.9	-1,600	2,800
179.6	-1,900	3,100
179.3	-1,800	2,700
179.0	-1,300	2,000
178.8	-850	700
178.5	-200	700
178.1	350	-275
177.9	400	-250
177.6	550	-200
177.3	700	-300
177.1	800	-525
176.8	650	-500
176.5	550	-400
176.2	475	-325
175.9	225	-100
175.7	100	100
175.4	-200	500
175.2	-300	600
174.9	-200	600
174.6	-300	500
174.3	-300	400
174.0	-500	100

(Continued)

Table C1 (Continued)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
173.7	-550	225
173.3	-400	200
173.0	650	-200
172.8	1,000	-600
172.5	1,125	-1,000
172.1	1,100	-750
171.9	700	-300
171.6	250	100
171.3	100	150
171.0	0	125
170.7	0	200
170.5	0	175
170.2	0	100
169.9	150	0
169.6	0	-175
169.3	0	-200
169.0	100	-100
168.7	75	0
168.4	0	25
168.1	0	100
167.9	-75	0
167.5	0	0
167.2	0	0
166.9	125	0
166.6	125	0
166.3	75	-150
166.0	100	-175
165.2	425	-400
164.9	600	-600
164.6	775	-775
164.2	725	-700
163.9	675	-450
163.6	400	-350
163.3	250	-260
163.0	250	-250
162.7	100	-175
162.4	0	-275
162.1	-75	0
161.8	-350	200
161.5	-200	375
161.2	-325	500
160.9	-100	450
160.6	-125	375
160.3	-200	200
160.0	0	0
159.6	0	0
159.3	0	0
159.0	75	-100
158.7	150	0
158.3	100	0
158.0	0	0
157.7	-100	0
157.4	0	-100
157.0	150	-225
156.7	600	-250
156.4	1,600	-1,125
156.1	1,550	-1,300
155.7	1,300	-850
155.4	925	-400
155.1	500	-250
154.8	200	-100
154.4	100	-200
154.2	125	-350
153.8	0	-400
153.5	0	-500
153.2	0	-275
152.9	-200	-100

(Continued)

(Sheet 4 of 10)

Table C1 (Continued)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
152.6	-325	100
152.3	-650	300
151.9	-750	500
151.7	-750	950
151.3	-1,000	1,400
151.0	-1,450	1,750
150.7	-1,700	1,775
150.4	-1,550	1,250
150.1	-900	550
149.8	50	-100
149.5	100	-200
149.2	200	-100
148.8	600	-200
148.4	200	-250
148.0	125	0
147.6	-125	50
147.3	0	0
146.9	-75	50
146.6	0	25
146.2	0	0
145.8	75	0
145.3	100	0
144.9	0	0
144.5	-350	0
144.1	-1,100	775
143.7	-1,350	1,450
143.3	-1,550	2,025
143.0	-1,750	2,000
142.6	-1,350	2,300
142.1	250	150
141.6	1,000	-700
141.2	700	-600
140.8	325	-300
140.4	0	-125
139.9	-100	0
139.4	-125	0
139.0	-100	75
138.5	0	0
138.1	-200	0
137.6	-400	175
137.2	-300	0
136.8	-100	-100
136.4	-100	-150
135.9	0	-300
135.4	1,675	-675
135.0	1,300	-900
134.6	1,400	-1,050
134.2	1,550	-1,050
133.8	1,350	-800
133.3	300	100
133.0	-350	200
132.5	-1,050	500
132.1	-1,725	1,500
131.7	-2,100	2,050
131.2	-1,500	1,500
130.9	-2,400	2,700
130.6	-2,250	2,600
130.2	-600	1,275
129.8	400	0
129.4	700	-300
129.0	550	-300
128.5	150	-300
128.05	50	-325
127.7	50	-300
127.3	0	0
126.9	0	-100
126.4	-125	-150

(Continued)

(Sheet 5 of 10)

Table C1 (Continued)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
126.0	75	-100
125.6	-100	0
125.2	-200	250
124.75	-300	875
124.4	-300	1,000
124.1	-300	500
123.7	-500	1,000
123.2	-375	625
122.7	0	-100
122.3	250	-250
121.8	600	-300
121.3	550	-456
120.8	150	-300
120.35	100	-100
119.9	-100	0
119.5	-150	-50
119.05	0	-100
118.6	100	-75
118.2	400	-300
117.9	325	-250
117.4	400	-350
117.0	150	-300
116.5	150	-250
116.1	100	-100
115.6	-125	-100
115.2	-250	50
114.8	-300	0
114.4	-275	50
114.0	-300	0
113.6	-300	50
113.2	-300	0
112.7	-400	150
112.3	-325	200
111.9	-150	200
111.6	-150	350
111.3	-200	200
110.95	-600	325
110.6	-575	700
110.3	-500	475
110.0	-400	400
109.7	-200	0
109.4	100	0
109.05	200	0
108.7	150	-150
108.3	100	-300
107.9	350	-200
107.5	600	-375
107.1	800	-250
106.6	650	-400
106.2	650	-400
105.7	650	-450
105.2	500	-200
104.9	200	100
104.6	-150	350
104.2	0	200
103.8	-100	350
103.4	-200	250
102.95	-75	0
102.5	-50	100
102.2	0	100
101.8	200	-100
101.4	550	-300
101.0	675	-450
100.6	550	-100
100.2	350	-100
99.7	550	-300
99.3	450	-100

(Continued)

(Sheet 6 of 10)

Table C1 (Continued)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
98.9	100	-100
98.4	50	-100
97.8	0	0
97.4	100	-150
97.0	0	100
96.6	0	0
96.2	75	-200
95.8	100	-100
95.3	0	0
94.9	0	0
94.4	0	0
94.1	-150	-100
93.7	-50	50
93.3	100	100
92.8	100	50
92.4	-50	0
91.95	100	100
91.5	0	0
91.05	0	0
90.3	0	0
89.9	-100	0
89.6	-150	-50
89.3	100	-200
89.0	200	-150
88.8	350	-200
88.5	600	-400
88.1	850	-950
87.8	100	-800
87.4	1,000	-1,000
87.1	1,000	-800
86.8	950	-850
86.5	1,100	-800
86.2	625	-750
85.9	0	-350
85.7	-100	0
85.4	-200	300
85.0	-200	300
84.7	-250	100
84.4	-300	0
84.1	-350	-100
83.8	-200	-200
83.4	-50	-300
83.1	0	-350
82.8	0	-200
82.6	-100	-50
82.3	0	0
82.0	-300	200
81.7	-450	650
81.4	-725	825
81.1	-850	1,200
80.8	-650	1,200
80.4	-400	850
80.1	-150	250
79.7	0	-200
79.4	-150	-150
79.0	-200	-200
78.7	-350	200
78.4	-350	150
78.1	-200	-175
77.8	375	-375
77.5	350	-325
77.3	350	-325
77.0	200	-350
76.6	100	-200
76.2	0	-200
75.8	-100	-125
75.5	-125	-100

(Continued)

(Sheet 7 of 10)

Table C1 (Continued)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
75.1	-275	0
74.8	-350	100
74.5	-450	125
74.2	-600	150
73.9	-300	0
73.5	-100	-150
73.2	-100	-400
72.9	50	-400
72.5	200	-400
72.2	400	-475
71.9	300	-300
71.5	-200	200
71.2	-175	100
70.8	-375	200
70.5	-200	200
70.2	-200	0
69.9	0	0
69.5	100	-50
69.2	150	-300
68.5	600	-1,000
68.1	1,250	-825
67.8	1,000	-500
67.5	500	-350
67.2	200	-350
66.8	75	-300
66.6	0	-150
66.2	0	-100
65.9	-150	-150
65.6	-250	0
65.2	-300	0
65.0	-400	-100
64.6	-400	0
64.3	-300	0
63.9	-200	100
63.5	-300	-100
63.2	-350	-100
62.9	-175	-250
62.6	0	-200
62.3	175	-200
62.0	150	-200
61.8	0	-200
61.4	-100	0
61.1	-200	0
60.7	-400	0
60.4	-500	250
60.1	-400	500
59.8	0	-100
59.6	450	-350
59.1	700	-400
58.8	400	-400
58.4	250	-300
58.0	-100	-200
57.7	0	-200
57.3	-200	-100
57.0	-200	-50
56.6	-150	-175
56.3	-150	-50
55.9	-200	-100
55.7	-250	-100
55.3	-100	-100
55.0	100	-200
54.7	0	-250
54.4	0	-250
54.0	0	-300
53.7	0	-350
53.5	0	-350
53.1	200	-350

(Continued)

(Sheet 8 of 10)

Table C1 (Continued)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
52.8	400	-250
52.5	425	-300
52.1	0	-50
51.7	-100	125
51.4	-200	100
51.1	-250	100
50.7	-300	0
50.3	-500	0
50.0	-450	100
49.7	-500	-50
49.3	-250	-100
49.0	-150	-150
48.6	0	-250
48.2	100	-250
47.8	0	0
47.5	0	0
47.2	-150	150
46.9	-100	300
46.5	-300	200
46.1	-250	150
45.8	-600	100
45.5	-750	100
45.2	-500	50
44.8	300	-450
44.4	1,000	-900
44.1	1,500	-1,125
43.7	1,500	-600
43.4	975	-100
43.0	200	0
42.7	-200	-50
42.3	300	0
41.9	260	50
41.6	-200	0
41.3	-150	0
41.0	-225	-50
40.7	-200	0
40.4	-150	0
40.0	-75	-75
39.6	-50	-200
39.3	-25	-250
39.0	0	-200
38.6	0	-300
38.3	-75	-200
38.0	-50	-200
37.6	-200	-250
37.3	0	-350
37.0	-75	-375
36.6	200	-450
36.2	500	-525
35.8	675	-600
35.5	650	-700
35.2	675	-825
34.9	100	-600
34.6	-200	-100
34.3	-500	200
33.8	-1,000	700
33.4	-1,750	950
33.0	-1,350	1,450
32.6	-550	900
32.3	-300	500
32.0	-300	125
31.6	-300	-100
31.3	0	-250
30.9	-125	-225
30.6	-75	-400
30.3	125	-400
30.0	450	-450

(Continued)

(Sheet 9 of 10)

Table C1 (Concluded)

Hydrographic Range Number	Descending Left Bank	Descending Right Bank
29.6	500	-350
29.3	400	-250
29.0	0	-400
28.6	-100	-275
28.3	-150	-400
28.0	-200	-225
27.6	-100	-250
27.3	-100	-150
26.9	-150	-250
26.6	0	-200
26.2	-50	-250
25.9	0	-300
25.6	0	-200
25.2	0	-250
24.8	600	0
24.4	0	0
24.0	-300	125
23.7	-500	100
23.4	-600	50
23.0	-600	75
22.8	-700	200
22.4	-500	0
22.1	-300	-50
21.9	0	-500
21.6	0	-900
21.3	150	-800
21.0	150	-450
20.6	0	-350
20.2	100	-450
19.9	-100	-400
19.6	-200	-200
19.4	-400	200
19.1	-500	300
18.8	-550	500
18.5	-300	-100
18.2	-250	-50
17.9	-150	0
17.6	-50	-100
17.3	-100	-100
17.0	0	0
16.7	-100	-100
16.4	-100	0
16.1	0	-75
15.9	0	-100
15.6	-50	0
15.3	0	0
15.0	-200	0
14.7	-200	0
14.4	-300	0
14.1	-100	0
13.8	-100	0
13.5	-200	0
13.2	-200	-125
12.9	0	-1[illegible]0
12.6	200	-200
12.4	0	-150
12.1	0	-200
11.8	200	-150
11.5	-300	100
11.2	-300	100
10.9	-325	-50
10.6	-300	100

END OF MAINLINE LEVEES

(Sheet 10 of 10)